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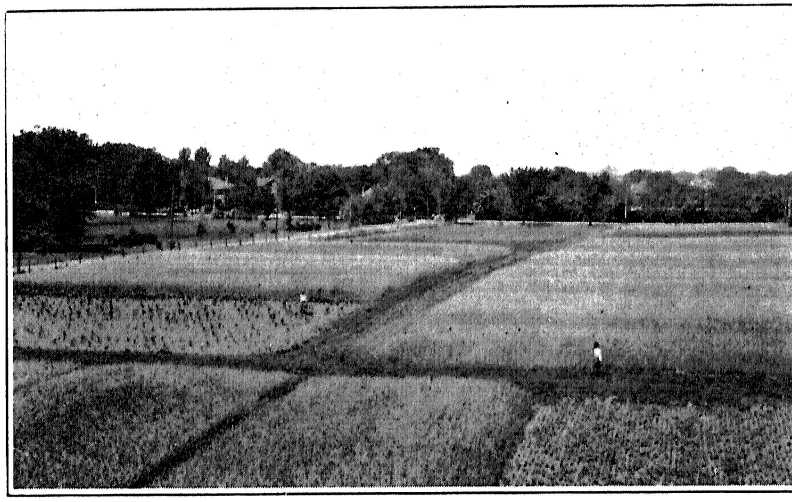
Thirty Years of Field Experiments With Crop Rotation, Manure and Fertilizers



General view of plots on Rotation Experiment Field at Columbia

COLUMBIA, MISSOURI
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UNIVERSITY OF MISSOURI

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Agricultural Experiment Station

Thirty Years of Field Experiments With Crop Rotation, Manure and Fertilizers

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Long continued experiments are necessary in order to determine the effects of systems of crop rotation and manuring upon the soil. Short time experiments mean little because of the influence of seasonal variations and because of the necessity of securing results from several rounds of the various rotations. The data here reported include the results of 30 years of experiments[1] with various systems of cropping, manuring, and fertilizing, designed to determine not only the effect upon crop yields but also upon the soil.

THE SOIL

The soil of the field on which these experiments have been conducted may be described as being of a dark, brownish-gray color and of a silt loam texture, 9 to 12 inches deep, grading into a grayish subsurface layer 4 to 6 inches thick. Below this there is another gradation into a brown, heavy clay loam rather impervious in character. The subsoil is a yellowish-gray, silty clay loam, more friable than the layer above it. The surface drainage is generally good. It is classed as Putnam silt loam although it differs slightly from the typical areas of this soil, in being slightly more rolling in topography, slightly deeper and somewhat darker in color. Also, the gray silt layer in the subsurface soil is not so pronounced and the tight clay loam layer in the upper subsoil is somewhat less impervious than in the typical Putnam silt loam. Plots 1-7, 23-26, and 29-33 inclusive are subject to slight erosion. The soil of the field is, however, fairly uniform in fertility.

THE PLAN OF THE EXPERIMENTS

The Plots: The experiments were begun in 1888, the original plan providing for 39 tenth-acre plots separated by alley-ways 3 feet wide. In 1904, owing to a change in a street on the north side of the field, it was necessary to shorten one range of plots somewhat and eliminate plot 8. It was considered wise to shorten the plots of the other ranges similarly so that all plots were reduced to one-thirteenth acre. To provide wider borders and improve the plan of handling they were further reduced to one-fourteenth acre in 1914.

[1]This experiment field was planned by J. W. Sanborn who was director of the Station in 1888 when the experiment was begun. The plots were laid out and the field work inaugurated by H. J. Waters who was at that time Assistant Agriculturist. Various men have been in charge of the detailed management of the plots at different times since. The work at this time is being handled by F. L. Duley. R. R. Hudelson has done most of the work in preparing the material for publication.

Cropping Plan: The original plan provided for the following systems of cropping and soil treatment:

Continuous Corn
Untreated ..... Plot 17
Manured ..... Plot 18

Continuous Oats
Untreated ..... Plot 16
Manured ..... Plot 15

Continuous Wheat
Untreated ..... Plots 9, 29
(29 not included in calculations.)
Manured .....Plots 5, 10, 21, 24, 30, 36
Fertilized ..... Plot 2

Continuous Clover
Untreated ..... Plot 7
(Changed to continuous cowpeas in 1909)
Manured .....Plot 6
(Changed to continuous cowpeas 1913)

Continuous Timothy
Untreated ..... Plot 23
Manured ..... Plot 22

Two Year Rotation: Wheat, Clover.
Untreated ..... Plot 33
Manured .....Plots 31, 32

Three Year Rotation: Corn, Wheat, Clover.
Untreated ..... Plot 27
Manured ..... Plots 25, 26, 28

Four Year Rotation: Corn, Oats, Wheat, Clover.
Untreated ..... Plot 39
Manured .....Plots 34, 35, 37, 38

Six Year Rotation: Corn, Oats, Wheat, Clover, Timothy, Timothy.
Untreated ..... Plot 13
Manured ..... Plots 1, 11, 12, 14, 19, 20
Fertilized ..... Plot 3
One-half application each of manure and fertilizer .....Plot 4

It will be observed that there were from two to six duplications of the manured plots in each rotation although for the untreated rotated plots, the continuously cropped plots and the fertilized plots no duplicates were provided. Further the plots were not arranged in series according to rotations and their irregular distribution over the field has made them very difficult to handle efficiently since it has been necessary to handle each plot separately. Lastly the failure to provide a plot for each crop each year in the various rotations has made it impossible to eliminate the seasonal factor. It is there-

Fig. 2.—The three year rotation of corn, wheat and clover. Upper row of pictures shows growth on plots receiving manure; lower row shows growth without manure.

fore, only after a long period of years has elapsed that the results can be summarized with any assurance of accuracy, even 30 years being too short a time to eliminate this source of error. The necessity for the duplication of plots was not so clearly recognized in the early days of experimental work in agriculture, when these plots were laid out.

In 1914 at the end of a quarter century the plan of certain of the duplicate manured plots was changed to include more modern methods of applying manure, lime and fertilizer. One plot of each treatment was retained, however, and only the records from these unchanged plots are included in the averages for the last five years of the 30-year period.

PLOT TREATMENT

The original plan of manured plots provided for an application of 6 tons per acre annually. The same applications per plot were continued after 1904 when the plots were reduced in size, thus making the rate, from 1904 to 1913, 7.8 tons per acre. After 1913 the rate was restored to 6 tons per acre. On one plot, No. 1, the original plan provided for an application of 7 tons per acre, the acre-application on this plot being 9.1 tons after 1904. Such applications of manure are much larger than is practical on the cultivated land of the average farm, and the effects upon the soil and crop are therefore intensified. Considerable difficulty has been experienced from the use of such large amounts of manure in stimulating weed growth on certain plots and in causing wheat and oats to lodge, often smothering out grass and clover crops sown with them.

The fertilizer treatments on plots 2, 3 and 4 were based on the amounts of plant food removed in maximum crops. Plot 2 which was grown to wheat continuously received sufficient nitrogen, phosphorus and potassium to equal the amounts of these elements contained in a 40-bushel wheat crop and the accompanying straw.

Plot 3 which was devoted to a 6-year rotation of corn, oats, wheat, clover, timothy and timothy received an application of fertilizer carrying the amounts of nitrogen, phosphorus, and potassium found in maximum yields of these respective crops, that is, corn 80 bushels with 2.4 tons stover, oats 60 bushels with 1.5 tons straw, wheat 40 bushels with 2 tons straw, and hay crops 3 tons.

Plot 4 which had the same rotation as plot 3 received one-half the usual application of manure and one-half the amount of fertilizer used on plot 3.

Standard analyses showing crop composition have been used in determining the fertilizer applications. Sodium nitrate has been used throughout as a nitrogen carrier, acid phosphate[1] as phosphorus carrier and muriate of potash as a carrier of potassium. An interesting thing about the composition of these fertilizer applications based on the composition of the crop is the manner in which they differ from present day fertilizers, especially in the nitrogen content. The following table gives the amounts of the different fertilizers which have been applied to each crop since 1915. Previous to that time the amount was figured annually from the best available crop analyses using as a basis the yields given in this table. Such fertilizer applications are of course

[1]An exception to the above was made in the use of dissolved bone black instead of acid phosphate from 1889 to 1899 and bone meal 1908 and 1909.

TABLE 1.—AMOUNTS OF FERTILIZER APPLIED IN A 6-YEAR ROTATION, ALSO WITH CONTINUOUS WHEAT.

ASSUMED YIELD	Pounds of Fertilizer Per Acre		
	Sodium Nitrate	Acid Phosphate[1]	Muriate of Potash
Corn, 80 bu. plus 2.4 tons stover	764	301	136
Oats, 60 bu. plus 1.5 tons straw	375	157	98
Wheat, 40 bu. plus 2 tons straw	495	209	111
Clover, 3 tons hay	774	245	216
Timothy, 3 tons hay (2 years)	464	147	170

[1]An exception to the above was made in the use of dissolved bone black instead of acid phosphate from 1889 to 1899 and bone meal 1908 and 1909.

not economical. The value of the experiment lies in the effect they have upon the maintenance of productivity and upon the physical and chemical composition of the soil.

METHODS OF CALCULATION

In the following tables all plots receiving a given treatment are averaged together. In a few cases records were omitted by accident chiefly through changes of administration in the early days when help was insufficient. All such cases are marked "omitted" in the detailed tables which appear in the appendix of this bulletin.

Where it was considered desirable to reduce all records to a common summary, it was necessary to choose a common denominator, and for this purpose the total crop value was chosen. This necessitated the selection of a set of prices and it was considered best to use the December first farm price recorded in the annual reports of the State Board of Agriculture for the 30 years, 1889 to 1918, covered by the field experiments. These prices are lower than those prevailing at present. They are: Corn 52 cents a bushel, oats 35 cents, wheat 86 cents and hay $8.95 a ton. No such record of prices is available for straw or corn fodder and the following prices were considered fair: Wheat straw $2.50, oat straw $3.00 and corn stover $2.00 per ton.

In computing costs of treatment manure was assumed to cost $1.00 a ton applied to the land and in computing the cost of fertilizers the pre-war prices of 20 cents a pound for nitrogen, 6 cents a pound for available phosphoric acid and 6 cents a pound for available potash were used. These were the prices used by the state fertilizer inspection service 1908 to 1911. All computations are on the basis of one acre.

ROTATIONS

The chief problem which this experiment was designed to solve is the determination of comparative values of different rotations when continued through a period of years. Table 2 gives in compact form the information bearing on this question. It is evident that the longer the period between corn crops the greater is the yield, varying from 20.9 bushels with corn every year to 32.6 bushels in a three-year rotation, 38.5 bushels in a four-year rotation and 41.5 bushels in a six-year rotation. This is to be expected since corn

is the only cultivated crop and hence the most exhaustive one in the series. A closer study of all the crops, however, seems to indicate that the four-year rotation gave best general results since it is a little better on oats, wheat and clover than the six-year rotation. Reducing to average values per acre the last column of the table bears out this observation.

TABLE 2.—AVERAGE YIELDS OF CROPS WITHOUT MANURE OR FERTILIZER.
(30 Year Average Expressed in Yield per Acre.)

Cropping System	Corn		Oats		Wheat		Clover	Timothy	Average Annual Value of Crop
	Grain bu.	Stover lbs.	Grain bu.	Straw lbs.	Grain bu.	Straw lbs.	Hay lbs.	Hay lbs.	
6 Year rotation	41.5	1899	27.2	1720	20.1	1914	2173	2446	$14.48
4 Year rotation	38.5	2940	27.9	1600	23.6	3314	2615	.....	17.82
3 Year rotation	32.6	2478	.....	.....	14.4	1717	1918	.....	14.18
2 Year rotation	.....	.....	.....	.....	18.4	2405	2974	.....	16.07
Corn continuously	20.9	2052	.....	.....	.....	.....	.....	.....	12.92
Oats continuously	.....	.....	16.9	1099	.....	.....	.....	.....	7.56
Wheat continuously	.....	.....	.....	.....	9.5	1241	.....	.....	9.72
Clover continuously	.....	.....	.....	.....	.....	.....	2430	.....	10.87
Timothy continuously	.....	.....	.....	.....	.....	.....	.....	2577	11.53

In all cases, growing the same crop continuously reduced the average value of the crop, which is probably due to several causes, among which is the favoring of enemies of a specific crop by continuing that crop on the same

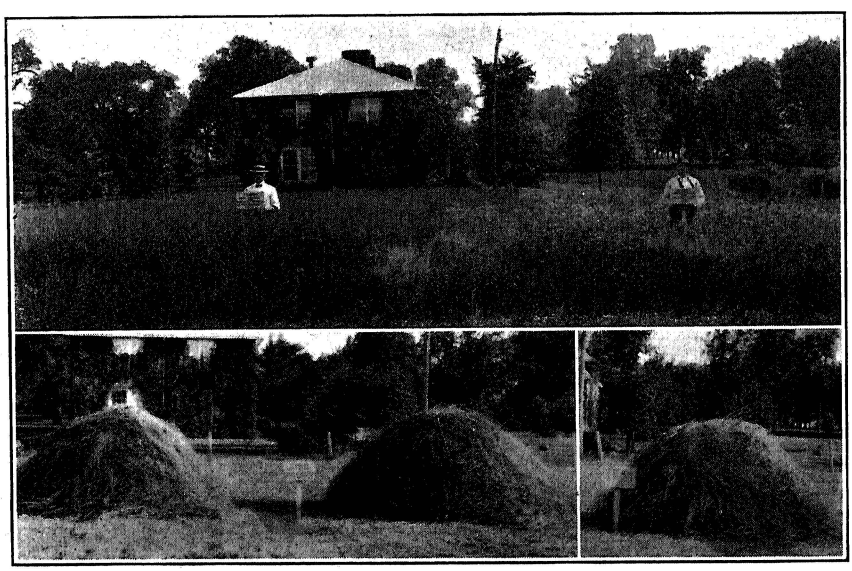


Fig. 3.—Continuous timothy heavily top-dressed with manure on left and without treatment on right. The manure has approximately doubled the yield and greatly lessened the number of weeds, particularly during recent years when the weakened condition of the untreated plot has allowed many weeds to come in.

field year after year. Insect enemies, weeds and diseases are all favored by this practice. All the grain crops gave approximately twice the yield under rotation that they gave under continuous cropping and of course there is much more profit in growing a given amount of produce in one year than in two, since the seed, interest, tax and labor costs are thus cut in half. On the other hand extending the rotation too long and putting the money crops too far apart may reduce profits.

Table 3 gives a summary of the effects of rotation and continuous cropping where all plots have been heavily manured annually. In this case enough fertility is supplied so that the factor of soil exhaustion is practically eliminated, but even under these conditions rotation gives better yields than a one-crop system. As to choice of rotations this table is not so conclusive. Apparently

TABLE 3.—AVERAGE YIELDS OF CROPS RECEIVING ANNUAL APPLICATIONS OF MANURE. (30 Year Average Expressed in Yield per Acre.)

Cropping System	Corn		Oats		Wheat		Clover	Timothy	Average Annual Value of Crop
	Grain bu.	Stover lbs.	Grain bu.	Straw lbs.	Grain bu.	Straw lbs.	Hay lbs.	Hay lbs.	
6 Year rotation	44.0	2987	25.7	1683	26.5	3680	3981	4335	$20.23
4 Year rotation	47.7	3181	28.9	1980	24.0	3427	4564	.....	21.60
3 Year rotation	43.4	3183	.....	.....	25.6	3342	3352	.....	22.32
2 Year rotation	.....	.....	.....	.....	23.5	3139	4777	.....	22.75
Corn continuously	34.9	2889	.....	.....	.....	.....	.....	.....	21.04
Oats continuously	.....	.....	27.3	1928	.....	.....	.....	.....	12.45
Wheat continuously	.....	.....	.....	.....	18.1	2456	.....	.....	18.64
Clover continuously	.....	.....	.....	.....	.....	.....	3257	.....	14.58
Timothy continuously	.....	.....	.....	.....	.....	.....	.....	4902	21.94

any system which discourages crop enemies and preserves a good tilth is satisfactory where the fertility is maintained by other means. It is then a question of introducing the most valuable crops and eliminating the crops of little value giving consideration to the question of labor distribution and the feeds needed. Maintaining fertility by means of manure presupposes a livestock system of farming.

Table 4 summarizes the results from using rotation and manure in corn production. It is doubtful if any other crop is so good for measuring these soil differences since corn is so universally grown in this section and it is the crop before which most of the manure is applied. From this table it is evident that in cases where the soil is not maintained by manuring, the corn yield

TABLE 4—AVERAGE YIELDS OF CORN OBTAINED UNDER DIFFERENT CROPPING SYSTEMS WITH AND WITHOUT MANURE, 30 YEAR AVERAGE.

Cropping System	Unmanured	Manured
Corn Continuously	20.9 bu.	34.9 bu.
3 Yr. Rotation	32.6 bu.	43.4 bu.
4 Yr. Rotation	38.5 bu.	47.7 bu.
6 Yr. Rotation	41.5 bu.	44.0 bu.

is increased by lengthening the period between corn crops up to at least five years; where manure is used liberally the six-year rotation is no more effective than the four-year rotation, but as there is no apparent reason for the six-year rotation falling below the shorter one, this result seems due to accidental variation in the plots or seasons averaged.

USE OF MANURE

It should be remembered in studying the effects of manure in these experiments that the amounts applied were greater than is feasible in any practical system of farming with the possible exception of intensive trucking. The comparative effects on different crops would probably remain the same with lighter applications, however, since the results agree in general with those from other experiment fields of the Experiment Station where practical applications have been made. It was often necessary to haul manure from livery stables in town and large amounts of weed seed were sometimes introduced. Clean cultivation reduced their damage to corn and they did not gain much of a foothold in an established stand of timothy. The excessive applications of manure often caused lodging of the wheat and oats crops and injured the clover following, both through smothering and through the introduction of weed seeds.

Table 5 shows the high value of manure on corn, wheat and timothy. From this table it is evident that manure is not so good on continuous clover. Much

TABLE 5.—AVERAGE ANNUAL YIELDS OF SINGLE CROPPED PLOTS MANURED AND UNMANURED, 30-YEAR AVERAGE.

CROP	Average Annual Yield		Average Increase from Use of Manure
	Manured	Unmanured	
Corn	34.9 bu.	20.9 bu.	14.0 bu.
Oats	27.3 bu.	16.9 bu.	10.4 bu.
Wheat	18.1 bu.	9.5 bu.	8.6 bu.
Clover	3257 lbs.	2430 lbs.	827 lbs.
Timothy	4902 lbs	2577 lbs.	2325 lbs.

of this is due to weed trouble and the difficulty of growing clover continuously. Clover often gives excellent returns for manure where the manure is applied to a preceding crop in the rotation, thus giving a chance to germinate and kill the weeds, or where the young clover is given a light top dressing. Oats is a poor crop on which to use manure. The increase in bushels of oats per acre is greater than the increase in wheat, but the lower price per bushel of oats makes the return smaller. Lodging was particularly bad on the manured oats plots.

In Table 6 the effects of manuring have been reduced to terms of money value. Timothy, wheat and corn show the largest crop values from the use of manure and they rank in the order named. This relative value is somewhat dependent on the crop prices selected, however, and the relatively high value returned by wheat is chiefly due to its greater value per bushel. The

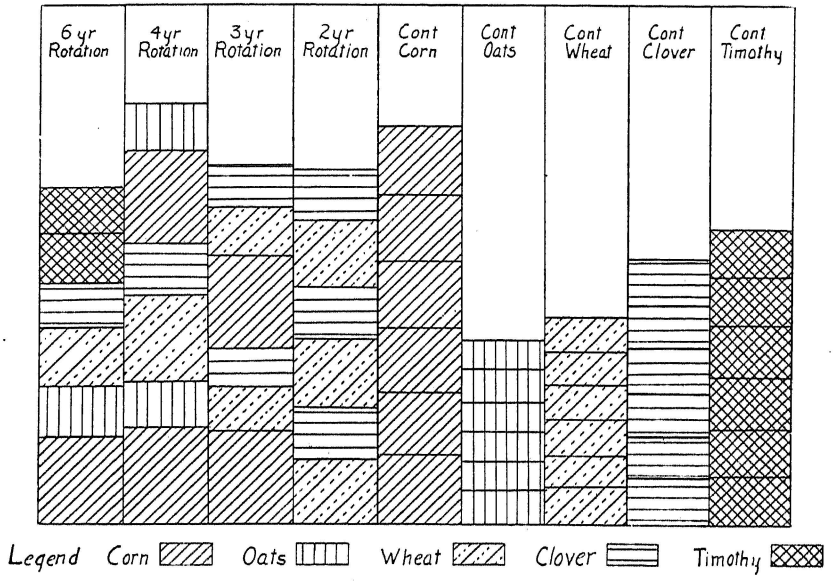


Fig. 4.—Total weight of crop produced on an acre in six years with continuous cropping and with different rotations (30-year average).

soil of Rotation Field is especially well adapted to timothy and it is less hampered by seasonal and soil limitations than the other crops. In these experiments it was very noticeable that a stand of timothy was maintained for longer periods where the soil was manured. On the continuous timothy plots the timothy on the unmanured plot often gave way to wild grasses and weeds and had to be reseeded at frequent intervals particularly during recent years, while the manured plot retained a clean, vigorous stand of timothy almost indefinitely. It was plowed up only for the purpose of treating the two plots alike when it became necessary to reseed the unmanured plot. A top dressing of manure on timothy is highly beneficial.

TABLE 6.—AVERAGE ANNUAL VALUE OF PRODUCE ON MANURED AND UNMANURED PLOTS FOR A 30-YEAR PERIOD.

Cropping System	Average Annual Value		Average Annual Increase for Manure
	Manured	Unmanured	
Corn continuously	$21.04	$12.92	$8.12
Oats continuously	12.45	7.56	4.89
Wheat continuously	18.64	9.72	8.92
Clover continuously	14.58	10.87	3.71
Timothy continuously	21.94	11.53	10.41
6-Year rotation	20.23	14.48	5.75
4-Year rotation	21.60	17.82	3.78
3-Year rotation	22.32	14.18	8.14
2-Year rotation	22.75	16.07	6.68

Table 7 indicates that the three-year rotation is a little less effective and the longer rotations more effective than heavy manuring in maintaining corn and wheat yields over a period of thirty years. Judging from the soil analysis it is evident, however, that manure is more effective in keeping up the soil than is rotation. In still longer periods than thirty years, therefore, rotation may not be so effective. A combination of rotation and manure is best. It is evident that rotation alone cannot maintain fertility since no combination of crops can put other fertility elements than nitrogen back into the soil. Proper use of a rotation may put nitrogen back through legumes if only the seed be harvested, and it may also reduce the amount of other elements removed, but so long as crops are sold some fertility is lost and the amount in any soil is definitely limited.

TABLE 7—COMPARATIVE EFFECTIVENESS OF ROTATIONS AND MANURE IN MAINTAINING YIELDS OF CORN AND WHEAT.

Crop	30 Year Average Yield				
	Single Cropping		Rotation without Manure		
	Without Manure	With Manure	3 yr	4 yr.	6 yr.
Corn	20.9	34.9	32.6	38.5	41.4
Wheat	9.5	18.1	14.4	23.6	20.1

COMMERCIAL FERTILIZER VERSUS MANURE IN MAINTAINING CROP YIELDS

Commercial fertilizers have come into common use very rapidly in Missouri. This has led to many questions about their value when used for a period of years, and the possibility that the continued use of fertilizers might have a harmful effect upon the soil. These 30-year-old experiments with fertilizers have therefore gained much in interest and value. Unfortunately only three plots receiving fertilizer were included in this experiment.

There is one plot of continuous wheat with enough fertilizer to replace all the nitrogen, phosphorus and potassium in 40 bushels of wheat and 2 tons of straw, one with a 6-year rotation on which enough fertilizer is applied to replace these elements of plant food in maximum crops, and one plot with 6-year rotation on which half this amount of fertilizer is applied together with 3 tons of manure, which is half the amount of manure applied on the manured plots of this experiment. These are very heavy applications, too expensive for practical use in general farming in Missouri, although no greater than are commonly used in trucking, potato growing, cotton farming or other types of intensive agriculture. Table 1 gives the rates of application of these fertilizers.

The materials were applied by carefully mixing them together and drilling or broadcasting either before the crop or as a top dressing on the crop. These large amounts of fertilizer sometimes interfered with germ-

ination when drilled in with the seed in case of wheat and two methods of avoiding this difficulty were tried with success. One method was to drill the fertilizer a few days before drilling the crop and the other was to broadcast the fertilizer as a top dressing in the spring. Drilling ahead of the crop has the advantage of furnishing an abundance of plant food to promote vigorous growth when the crop is getting a start and the fertilizer is not likely to interfere seriously with germination since fertilizer and seed are in different drill furrows.

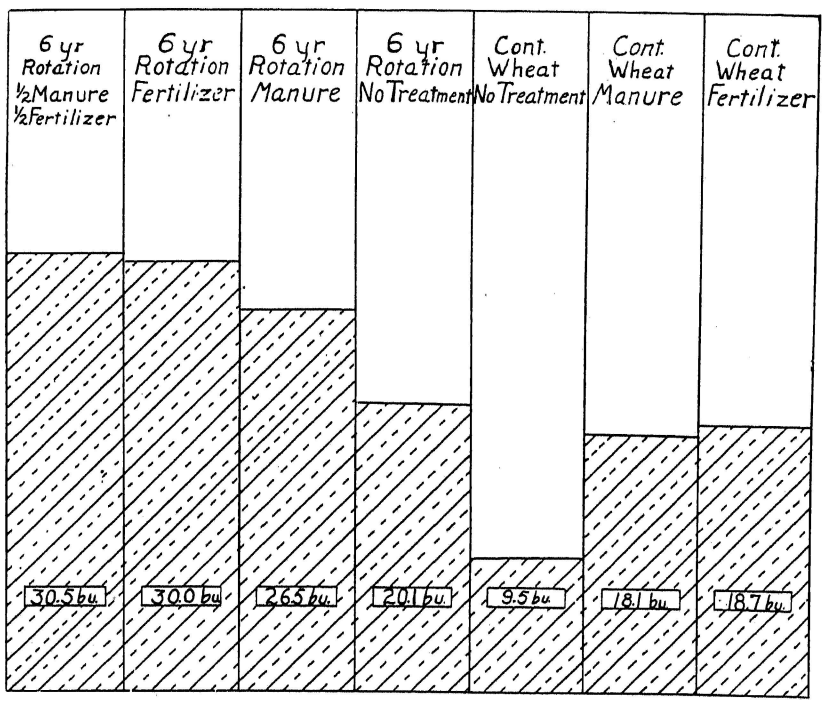


Fig. 5.—Effects of rotation, manure and fertilizer on wheat yields (30-year average).

Table 8 gives the crop yields on the plots receiving commercial fertilizer in comparison with yields on untreated and manured plots.

From Table 8 it may be seen that fertilizers have kept up the yields as well as manure when averaged for 30 years. Corn and the hay crops are better with manure, but wheat and oats are better with fertilizer. In fact oats yielded less with manure than without, which can only be explained in the increased lodging of oats where manure was applied so heavily.

In general, this relative response of the different crops to manure and fertilizer agrees with numerous other experiments of the Missouri Experiment Station. The Rothamsted Experiment Station in England and the Pennsylvania Experiment Station in this country have also demon-

TABLE 8.—FERTILIZED AND MANURED PLOTS IN COMPARISON. YIELDS FOR 30 YEARS UNDER SINGLE CROPPING AND 6-YEAR ROTATION SYSTEMS.

Cropping System	Yields			
	Untreated	Manured	Complete Fertilizer	½ Manure ½ Fertilizer
Wheat continuously	9.5 bu.	18.1 bu.	18.7 bu.	.....
Six-Year rotation				
Corn	41.5 bu.	44.0 bu.	41.6 bu.	36.8 bu.
Oats	27.2 bu.	25.7 bu.	39.1 bu.	37.6 bu.
Wheat	20.1 bu.	26.5 bu.	30.0 bu.	30.5 bu.
Clover	2173 lbs.	3981 lbs.	3636 lbs.	3580 lbs.
Timothy (average 2 years)	2446 lbs.	4335 lbs.	3810 lbs.	3652 lbs.

strated the possibility of maintaining crop yields for long periods of time by the use of heavy applications of chemical fertilizers as readily as by the use of farm manure. The comparative effects of manure and fertilizers on wheat have been observed many times on the experiment fields of Missouri, as well as those of other states. Wheat when manured makes a good growth of straw but when it begins to head out is usually spotted and ripens unevenly, while wheat fertilized with a material high in available phosphate usually matures evenly, with a very uniform appearance, due to the uniformity in height, size of heads and color. Wheat fertilized with a phosphatic fertilizer almost invariably matures a few days earlier than unfertilized or manured wheat.

An interesting observation in case of the plots receiving fertilizer only, even the one cropped continuously to wheat, is that the soil is not ap-

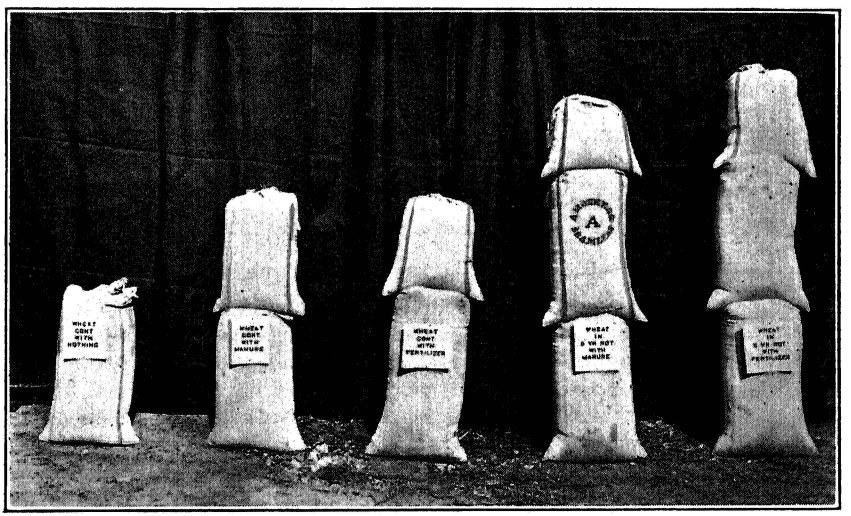


Fig. 6.—Average yield of wheat on equal areas. From left to right the average yields in bushels per acre are as follows: Continuous wheat without treatment, 9.5; continuous wheat with manure, 18.1; continuous wheat with fertilizers, 18.7; wheat in six year rotation with manure, 26.5; wheat in six year rotation with fertilizers, 30.0.

preciably more compact than that of similarly cropped plots without treatment. It might be expected that the large quantities of sodium nitrate applied would tend to puddle the soil to a certain extent but such a condition has not been observed.

A general summary reduced to values, is shown in Table 9. The figures for cost of production are taken from Missouri Bulletin No. 125 which covers the period preceding the war. They do not take into account any extra expense in harvesting and marketing the crop increases from soil treatment. Probably the most important point shown by this table is that rotations, in general, bring greater returns than single cropping. It is evi-

TABLE 9.—ANNUAL NET RETURN PER ACRE WITH COSTS, AVERAGED FOR 30 YEARS.

Crop and Treatment	Average Annual Value	Cost of Production	Cost of Manure or Fertilizer	Total Cost	Net Gain
6-Year rotation No treatment	$14.48	$10.83	.....	$10.83	$3.65
6-Year rotaton Manured	20.23	10.83	$6.60	17.43	2.80
6-Year rotation Complete fertilizer	20.46	10.83	21.15	31.98	—11.52
6-Year rotation ½ manure; ½ fertilizer	19.69	10.83	13.88	24.71	— 5.02
4-Year rotation No treatment	17.82	11.50	.....	11.50	6.32
4-Year rotation Manured	21.60	11.50	6.60	18.10	3.50
3-Year rotation No treatment	14.18	11.83	.....	11.83	2.35
3-Year rotation, Manured	22.32	11.83	6.60	18.43	3.89
2-Year rotation, No treatment	16.07	11.00	.....	11.00	5.07
2-Year rotation, Manured	22.75	11.00	6.60	17.60	5.15
Corn continuously, No treatment	12.92	13.50	.....	13.50	— .58
Corn continuously, Manured	21.04	13.50	6.60	20.10	.94
Oats continuously, No treatment	7.56	10.50	.....	10.50	— 2.94
Oats continuously, Manured	12.45	10.50	6.60	17.10	— 4.65
Wheat continuously, No treatment	9.72	12.50	.....	12.50	— 2.78
Wheat continuously, Manured	18.64	12.50	6.60	19.10	— .46
Wheat continuously, Complete fertilizer	19.15	12.50	18.40	30.90	—11.75
Clover continuously, No treatment	10.87	9.50	.....	9.50	1.37
Clover continuously, Manured	14.58	9.50	6.60	16.10	— 1.52
Timothy continuously, No treatment	11.53	9.50	.....	9.50	2.03
Timothy continuously. Manured	21.94	9.50	6.60	16.10	5.84

dent also that both manure and fertilizer were used in too large quantities to pay. For general farm crops the cost of manure and fertilizer must be kept down to correspond with the value of the product. Heavy applications increase the gross return per acre, but in general the return per unit of fertilizer is greater as the quantity of fertilizer per acre is reduced. Experience and judgment must determine that amount of manure or fertilizer which in normal seasons proves best adapted to the particular set of conditions under which a given farm is operated.

It is evident that these heavy applications of chemicals were not profitable under the existing conditions. Manure was better even though it was used in very large quantities. The use of half manure and half fertilizer was better than fertilizer alone. It is evident that the chief source of financial loss in this fertilizer is the high cost of so much nitrogen. The general farmer must get most of his nitrogen from cheaper sources than commercial fertilizer. Legumes must be used increasingly and constantly if yields are to be kept up economically. Losses of nitrogen must be constantly watched and prevented, especially in the liquid manure which contains almost half of the nitrogen in the manure. The potash applied to these fertilized plots was also excessive. Potash is abundant in this soil and needs only to be made available. The phosphates used were not so excessive and these quantities, which varied from 150 to 300 pounds of acid phosphate per acre, have often proved profitable when used alone or in connection with small amounts of nitrogen and of potassium. In fact 150 to 200 pounds is the rate commonly used on the experiment fields of the Missouri Experiment Station and recommended to Missouri farmers. Three hundred pounds is the maximum ever recommended for field crops. Climatic and soil conditions effectively limit the amounts of fertilizer that can economically be applied to general field crops in Missouri.

Maintenance of Crop Yields. Relative Yields of Crops by Five-Year Periods: Figures 7 and 8 show diagramatically the yield in total weight of dry matter under the different cropping systems and treatments used on Rotation Field when averaged by five-year periods In the lower half of the chart the length of the black or cross-hatched blocks is proportional to the yield of crops. The curves in the upper half of the chart show the trend of the yields. They are parallel to the tops of the cross-hatched blocks below. A study of these charts will show whether or not the yield is being maintained under each treatment.

Seasonal variation complicates these records leaving them somewhat indefinite in many instances but the following observations seem justified.

The yield was unmistakably increased where the three and four-year rotations were used and the land manured. The curve seems inclined upward also where the two-year rotation is manured, but the effect is produced largely by unusually favorable conditions during the last five years.

Where the six-year rotation is used with manure, fertilizer, or half manure and half fertilizer the curve is approximately level, indicating maintenance but no increase. Considering the ability of continuous timothy to maintain a rather high level of nitrogen and organic matter there is no apparent explanation for the seeming inferiority of the six-year compared with shorter rotations in maintaining crop yields.

The curve is also nearly level for the two, three, and four-year rota-

tions without manure. It is likely that somewhat improved methods of cultivation and management have balanced any downward tendency in yield on these plots. Later records should show whether or not there is actual soil maintenance.

The yield has apparently decreased in the case of all continuous crops without manure or fertilizer although the downward tendency is not so marked with continuous oats. It is most conclusive for corn and timothy.

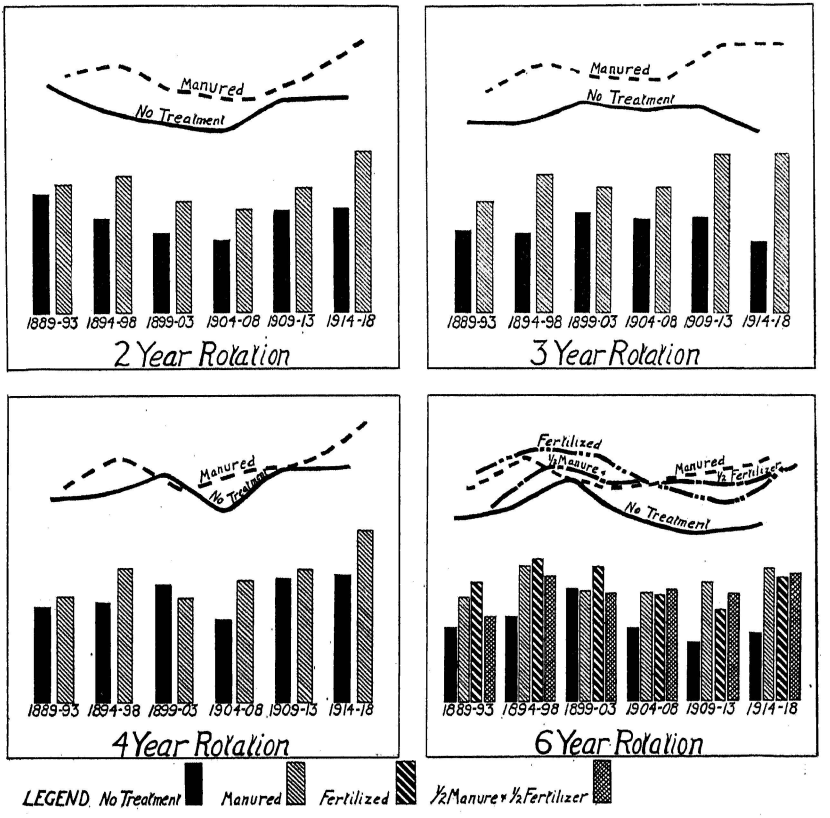


Fig. 7.—Yields in total weight of dry matter under different cropping systems and treatments by five-year periods.

The oats crop is not well adapted to the climatic conditions in Central Missouri so that the yields average low. There is, therefore, less tendency to soil exhaustion. With continuous corn and continuous timothy the yields have run down even where manured. The one exception to this is the last period with corn when exceptionally favorable conditions have apparently brought the yield up again.

Although the 30-year average yields previously discussed indicate that heavy applications of fertilizer have generally given as good yields as manure, a study of the chart showing the six-year rotation under different

treatments shows that fertilizer exceeded manure in total weight of crop during the first three periods or half of the time included, but manure gained the ascendency through the last three periods. Half manure and half fertilizer stood lowest of the three treatments for the first three periods but for the remainder of the time stood first or second with the fertilizer plot standing in third place. There is at least an indication here that manure or a combination of manure and fertilizer is superior to fertilizers alone in maintaining soil fertility through long periods of time.

SOIL MAINTENANCE

The efficiency of any system of soil management will depend not alone upon its ability to produce an immediate profit, but upon its ability to maintain soil fertility and guarantee a permanent productivity. There is no better single index to the maintenance of the soil of different plots in the same field than their nitrogen content. Besides the value of nitrogen itself, it is a fairly accurate indicator of the amount of organic matter remaining in the soil. Figure 8 shows very clearly the effect of different

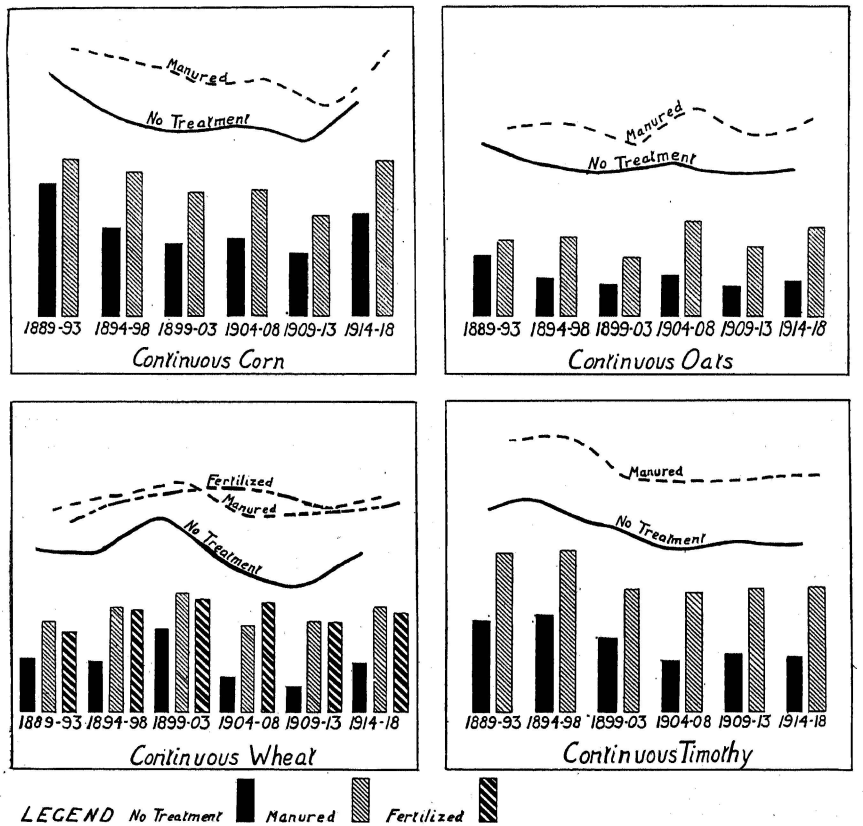


Fig. 8.—Yields in total weight of dry matter with various crops grown continuously on the same land and without soil treatment.

methods of management on the nitrogen remaining in the soil after 25 years of cropping, the soil samples having been taken at that time.

Corn is clearly the most exhaustive crop on the nitrogen supply, followed by oats and wheat which do not differ greatly, and finally by timothy which appears to be less exhaustive than any of the other crops. It will be remembered that it proved impossible to grow clover continuously. Rotations have been less exhaustive of soil nitrogen than any single crop except timothy. This results from the fact that all rotations contain legume or sod crops or both. It may also be due to nitrogen fixation through azotobacter or similar free nitrogen fixing forms in timothy sod as shown by Rothamsted data.

Chemical fertilizers, although maintaining yields when used in large quantities, have not kept up the soil nitrogen. Evidently most of the nitrogen not used by the immediate crop was removed from the soil by leaching or denitrification. It should be said in this connection, however, that the plots receiving chemical fertilizers are located on a part of the field which slopes slightly more than the average and a small amount of erosion takes place. It is almost certain that some of the loss of nitrogen may be explained by this fact. Other plots similarly located but not fertilized with commercial nitrogen are very little below the average, however, and surface erosion does not explain the large loss of nitrogen where fertilizers were used.

As nitrogen is a fair indicator of the supply of organic matter in the soil, this data has an interesting bearing on statements sometimes made in soil literature that the heavy use of commercial fertilizers tends to maintain organic matter through increased production of roots and stubble. There is little evidence to sustain this view in these experiments if the nitrogen content be used as the indicator. The nitrogen in the continuous wheat plot receiving large amounts of fertilizer is appreciably less than that in the continuous wheat plot without treatment. However, as has been mentioned, the last named plot suffers somewhat less from erosion which, in the light of other experiments at this station, might account for the observed difference. If a comparison is made between the six-year rotation plot receiving fertilizers only and the plot with the same rotation without treatment, it will be seen that the fertilized one contains more nitrogen, but only very slightly more, than the one without treatment. Here again the slope of the fertilized plot is a little greater than that of the untreated one.

Manure has been very effective in keeping up the nitrogen supply and all plots receiving the full annual application of 6 tons of manure per acre stand higher in nitrogen than the soil on the driveways, which has never been cropped and which has only occasionally had the bluegrass and weeds removed when they were allowed to get too tall before clipping. Of all the plots receiving a full application of manure the continuous timothy plot stands highest in nitrogen. The non-cultivated crops, wheat and oats, stand higher than corn. This bears out the well known fact that stirring the soil hastens decomposition of the organic matter by increasing the air supply in the surface soil thus promoting nitrogen loss.

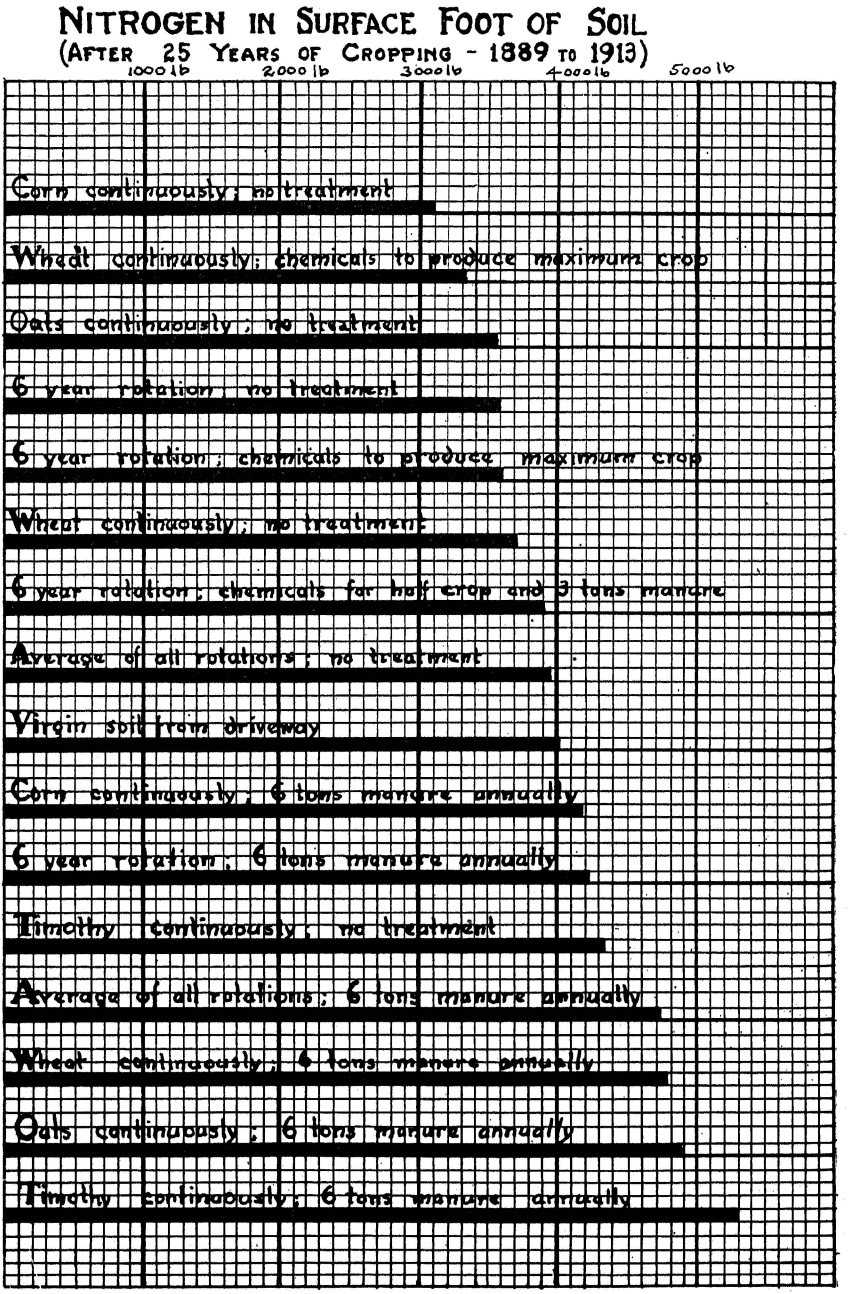


Fig. 9.—Nitrogen in surface foot of soil, after 25 years of cropping (1889 to 1913).

SOIL MANAGEMENT

In the light of these old experiments it is evident that systems of soil management which produce an immediate profit and at the same time provide for a continuation of that profit by maintaining or increasing the fertility of the soil will require careful and intelligent planning. The only exception to this, as shown by these experiments, is that of growing continuous timothy, an impractical plan in all but a very few localities of the State.

Organic matter and nitrogen must be maintained and this requires the use of a minimum of cultivated crops, since cultivation hastens the loss of nitrogen and organic matter. As many legume and sod crops must be used as the particular type of farming will profitably admit. The four-year rotation of corn, oats, wheat, and clover which has long been popular with many farmers seems a little the best of those tried. In this case the land is in a cultivated crop only one-fourth of the time which is enough on any but strong soils. Even strong soils will deteriorate if more corn is grown, unless more than ordinary care is taken to return manure, green manure or crop residues and it is cheaper to keep soil at a high producing capacity than it is to restore it after it becomes exhausted.

Not all the methods of maintaining organic matter were included in these experiments. The use of crop residues and green manure crops should be considered in most plans of soil management.

If legume crops are used liberally in the plan for keeping up organic

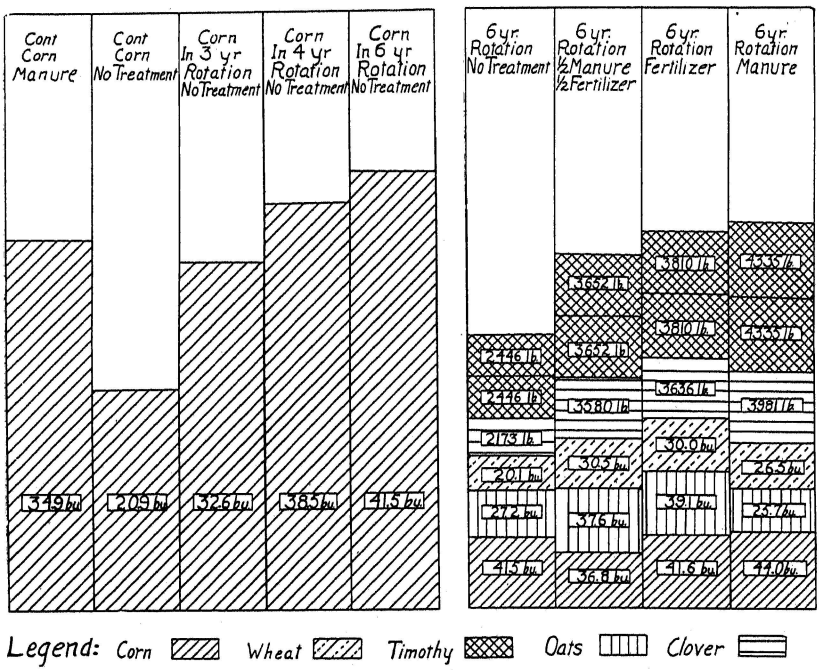
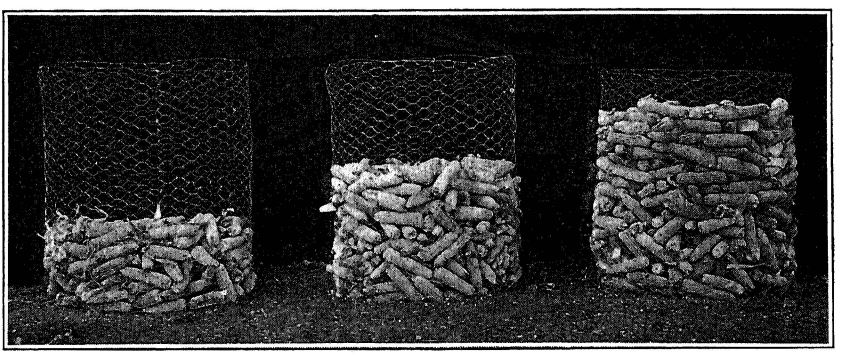


Fig. 10.—Left: Effect of manure and rotation on corn yields (30-year average.) Right: Crop yields in six year rotation with different soil treatments (30-year average).

matter, nitrogen will be taken care of in the same plan. For general farming purposes in Missouri nitrogen should only be bought for general field crops on the thinner lands where there is not time enough to build up soils by the slower but better method of growing legumes. Even in such cases the amount should not be large since such applications are prohibited by the expense.

Keeping up organic matter and keeping the soil in good physical condition largely take care of the potash problem for most Missouri soils since they contain much potash and it is largely a question of hastening its availability. Potash, like nitrogen, is advisable for general crops only in rather small quantities. Its use is advisable only in mixed fertilizers on soils relatively low in available potash.



Continuous corn with no treatment, 20.9 bu. per acre. Corn in 3 yr. rotation with no treatment, 32.6 bu. per acre. Corn in 3 yr. rotation manured, 43.4 bu. per acre.

Fig. 11.—Average annual yield of corn from plots variously treated during 30 years.

The one element of fertility which must be purchased in a system of general farming, livestock farming or grain farming is phosphorus. All products of the farm contain it and nearly all soils have a very limited supply. It may be purchased as acid phosphate, bonemeal, or ground rock phosphate. These and other experiments of long duration have shown that the acid added in making phosphates available has no appreciable harmful effects upon the soil. The phosphate in bonemeal is partly available the first year and most of the remainder during succeeding years. For immediate profit and a quick turnover of the investment one of the forms containing quickly available phosphate should be used.

SUMMARY

1. These field experiments with crop rotations, manure and fertilizers, were begun in 1888 and 30 years' results are here reported.

2. In general, crop rotations gave better yields than were secured from crops grown continuously without rotation.

3. Among the rotations used, the four-year rotation of corn, oats, wheat and clover gave somewhat better results than the others.

4. Crop rotation without manure was practically as effective in maintaining the average yields of corn and wheat as was heavy manuring where these crops were grown continuously without rotation.

5. Manure was more effective in maintaining a high average yield of corn and grass in a six-year rotation than was heavy fertilization with chemical fertilizers, but the reverse was true in the case of wheat and oats.

6. When measured by the 30-year average yield, heavy applications of chemical fertilizers were as effective as heavy applications of barnyard manure in maintaining the total produce in a six-year rotation of corn, oats, wheat, clover, timothy and timothy, but when averaged by successive five-year periods, the results indicate a growing superiority of manure or a combination of manure and fertilizer.

7. Soil analyses, at the end of 25 years, indicated that the most important factor in soil exhaustion was the loss of nitrogen and organic matter.

8. The crops grown continuously without rotation or manure stood in the following general order with reference to the reduction of the supply of nitrogen: First, corn; second, oats and wheat; third, hay crops.

9. Heavy applications of barnyard manure were very effective and heavy applications of chemical fertilizers were ineffective in maintaining the supply of soil nitrogen.

10. Crop rotation was more effective on the average than continuous cropping to grain crops, but less effective than continuous cropping to grass, in maintaining soil nitrogen.

APPENDIX

The following tables give the complete crop data from all plots used in the 30-year summary of the results of the experiments. Where a crop failure has resulted because of soil limitations, due to the cropping system used or the treatment given, the fact is indicated in the tables by the symbols 0000. Where there is an absence of records, due to other causes such as injury from chinch bugs, attacks by birds or incomplete data, the year is omitted in computing averages and is so indicated.

PLOT NO. 1

6-YEAR ROTATION: CORN, OATS, WHEAT, CLOVER, TIMOTHY, TIMOTHY

*Manured Annually

Year	Crop	Yield	
		Grain	Forage
1889	Wheat.....	13.27	2160
1890	Timothy.....	.....	0000
1891	Timothy.....	.....	Omitted
1892	Corn.....	61.43	2060
1893	Oats.....	36.25	3680
1894	Clover.....	.....	5500
1895	Wheat.....	44.00	4160
1896	Clover.....	.....	1000
1897	Timothy.....	.....	6540
1898	Corn.....	35.00	2080
1899	Oats.....	41.00	2890
1900	Clover.....	.....	6300
1901	Wheat.....	40.10	5595
1902	Timothy.....	.....	1950
1903	Omitted.		
1904	Corn.....	46.06	2600
1905	Oats.....	19.06	1443
1906	Timothy.....	.....	2730
1907	Wheat.....	28.20	3634
1908	Timothy.....	.....	7216
1909	Timothy.....	.....	7618
1910	Corn.....	50.30	6864
1911	Oats.....	24.07	1100
1912	Wheat.....	15.16	2587
1913	Clover.....	.....	3887
Average Corn.....		48.2	3401
Average Oats.....		30.1	2278
Average Wheat.....		28.1	3627
Average Clover.....		.....	4172
Average Timothy.....		.....	4342

* 7 tons manure per acre annually, 1889-1903; 9.1 tons per acre annually;1904-1913; 6 tons per acre annually, 1914-1918.

PLOT NO. 2

WHEAT CONTINUOUSLY

*Complete Fertilizer for Maximum Wheat Crop

Year	Crop	Yield	
		Grain	Forage
1889	Wheat.....	20.58	3225
1890	Wheat.....	Omitted	Omitted
1891	Wheat.....	24.60	2665
1892	Wheat.....	13.33	1980
1893	Wheat.....	00.00	0000
1894	Wheat.....	34.53	3700
1895	Wheat.....	39.33	4140
1896	Wheat.....	12.50	1570
1897	Wheat.....	10.80	1100
1898	Wheat.....	3.30	1400
1899	Wheat.....	16.10	1434
1900	Wheat.....	17.30	2040
1901	Wheat.....	28.70	3780
1902	Wheat.....	26.60	2650
1903	Wheat.....	18.70	3880
1904	Wheat.....	Omitted	Omitted
1905	Wheat.....	7.90	1024
1906	Wheat.....	33.36	4323
1907	Wheat.....	27.90	3616
1908	Wheat.....	14.10	1827
1909	Wheat.....	23.00	2474
1910	Wheat.....	Omitted	Omitted
1911	Wheat.....	16.46	2184
1912	Wheat.....	7.69	1515
1913	Wheat.....	17.01	2990
1914	Wheat.....	20.32	2741
1915	Wheat.....	Omitted	Omitted
1916	Wheat.....	10.5	2674
1917	Wheat.....	6.5	1162
1918	Wheat.....	34.3	3346
Average Wheat.....		18.7	2455

* Annual applications of enough sodium nitrate, dissolved bone, steamed bone or acid phosphate, and muriate of potash to replace all the nitrogen, phosphorus and potassium removed in a 40-bushel crop of wheat with 2 tons of straw.

PLOT NO. 3

6-YEAR ROTATION: CORN, OATS, WHEAT, CLOVER, TIMOTHY, TIMOTHY

*Complete Fertilizer for Maximum Crops

Year	Crop	Yield	
		Grain	Forage
1889	Wheat.....	17.67	2780
1890	Timothy	.....	0000
1891	Timothy	Omitted	Omitted
1892	Corn.....	60.71	4590
1893	Oats.....	38.75	4340
1894	Clover.....	.....	3140
1895	Wheat.....	38.67	4180
1896	Clover.....	.....	3740
1897	Timothy.....	.....	8220
1898	Corn.....	34.10	1700
1899	Oats.....	39.40	3200
1900	Clover.....	.....	4700
1901	Wheat.....	43.30	5790
1902	Timothy.....	.....	2120
1903	Omitted.		
1904	Corn.....	41.60	2340
1905	Oats.....	36.56	1106
1906	Cowpeas.....	.....	1690
1907	Wheat.....	24.08	3121
1908	Timothy.....	.....	6318
1909	Timothy.....	.....	3888
1910	Corn.....	46.20	3302
1911	Oats.....	17.88	754
1912	Wheat.....	21.99	1320
1913	Clover.....	.....	2964
1914	Timothy.....	.....	527
1915	Timothy.....	.....	5600
1916	Corn.....	25.6	4340
1917	Oats.....	62.7	2764
1918	Wheat.....	34.18	3773
Average Corn.....		41.6	3254
Average Oats.....		39.1	2433
Average Wheat.....		30.0	3494
Average Clover.....		.....	3636
Average Timothy.....		.....	3810

* Annual applications of enough nitrogen as sodium nitrate, phosphorus as dissolved bone, steamed bone, or acid phosphate and potassium as muriate of potash to replace all the nitrogen, phosphorus and potassium removed in a maximum crop. A maximum crop was assumed to be: 40 bu. wheat with 2 tons straw, 80 bushels of corn with 2.4 tons of stover, 60 bushels of oats with 1.5 tons of straw, and 3 tons of clover or timothy hay.

PLOT NO. 4

6-YEAR ROTATION: CORN, OATS, WHEAT, CLOVER, TIMOTHY, TIMOTHY

*Manure ½ Application
†Fertilizers for Half Maximum Crop.

Year	Crop	Yield	
		Grain	Forage
1889	Wheat.....	15.83	1800
1890	Timothy.....	.....	0000
1891	Timothy.....	.....	Omitted
1892	Corn.....	52.14	1880
1893	Oats.....	32.19	3770
1894	Clover.....	.....	3480
1895	Wheat.....	42.50	5000
1896	Clover.....	.....	2700
1897	Timothy.....	.....	5750
1898	Corn.....	30.00	1580
1899	Oats.....	44.70	3065
1900	Clover.....	.....	4320
1901	Wheat.....	43.30	4340
1902	Timothy.....	.....	2350
1903	Timothy.....	.....	1700
1904	Corn.....	27.70	1495
1905	Oats.....	30.88	2667
1906	Cowpeas.....	.....	1950
1907	Wheat.....	24.80	3214
1908	Timothy.....	.....	7138
1909	Timothy.....	.....	6254
1910	Corn.....	46.80	2366
1911	Oats.....	14.83	798
1912	Wheat.....	17.66	2295
1913	Clover.....	.....	3822
1914	Timothy.....	.....	788
1915	Timothy.....	.....	5236
1916	Corn.....	27.2	4676
1917	Oats.....	65.5	2688
1918	Wheat.....	39.2	3654
Average Corn.....		36.8	2399
Average Oats.....		37.6	2598
Average Wheat.....		30.5	3384
Average Clover.....		.....	3580
Average Timothy.....		.....	3652

* 3 tons manure per acre annually, 1889-1903; 3.9 tons, 1904-1913; 3 tons, 1914-1918.

†One-half as much fertilizer as applied on Plot 3, using the same materials.

PLOT NO. 5

WHEAT CONTINUOUSLY

*Manured Annually

Year	Crop	Yield	
		Grain	Forage
1889	Wheat.....	8.08	1100
1890	Omitted.		
1891	Wheat.....	27.92	2715
1892	Wheat.....	8.83	2290
1893	Wheat.....	0.00	0000
1894	Wheat.....	30.17	2390
1895	Wheat.....	34.33	3840
1896	Wheat.....	11.83	1930
1897	Wheat.....	13.80	1825
1898	Wheat.....	4.00	1100
1899	Wheat.....	13.60	1304
1900	Wheat.....	19.30	2380
1901	Wheat.....	23.30	3160
1902	Wheat.....	35.20	6210
1903	Wheat.....	17.26	2632
1904	Wheat.....	Omitted	Omitted
1905	Wheat.....	12.35	1601
1906	Wheat.....	7.15	927
1907	Wheat.....	17.10	2216
1908	Wheat.....	14.50	1879
1909	Wheat.....	00.00	0000
1910	Wheat.....	12.68	2968
1911	Wheat.....	6.50	1196
1912	Wheat.....	12.56	1970
1913	Wheat.....	15.93	3081
Average Wheat.....		15.00	2118

* 6 tons manure per acre annually, 1889-1903 ;7.8 tons, 1904-13.

PLOT NO. 6

CLOVER CONTINUOUSLY

*Manured Annually

Year	Crop	Yield	
		Grain	Forage
1889	Clover.....	.....	4200
1890	Clover.....	.....	5600
1891	Clover.....	.....	3620
1892	Clover.....	.....	3000
1893	Clover.....	.....	3680
1894	Clover.....	.....	4040
1895	Clover.....	.....	4800
1896	Clover.....	.....	2800
1897	Clover.....	.....	1900
1898	Clover.....	.....	3000
1899	Clover.....	.....	5180
1900	Clover.....	.....	1400
1901	Clover.....	.....	2440
1902	Clover.....	.....	3200
1903	Clover.....	.....	Omitted
1904	Clover.....	.....	Omitted
1905	Clover.....	.....	Omitted
1906	Clover.....	.....	Omitted
1907	Clover.....	.....	Omitted
1908	Clover.....	.....	0000
1909	Cowpeas.....	.....	3562
1910	Cowpeas.....	.....	7852
1911	Cowpeas.....	.....	4000
1912	Cowpeas.....	.....	6500
1913	Cowpeas.....	.....	2210
Average Clover.....		.....	3257
Average Cowpeas.....		.....	4825

* 6 tons manure per acre annually, 1889-1903; 7.8 tons 1904-1913.

PLOT NO. 7

CLOVER CONTINUOUSLY

No Manure or Fertilizer

Year	Crop	Yield	
		Grain	Forage
1889	Clover	.....	2600
1890	Clover	.....	4300
1891	Clover	.....	3720
1892	Clover	.....	2850
1893	Clover	.....	1420
1894	Clover	.....	2550
1895	Clover	.....	3500
1896	Clover	.....	2300
1897	Clover	.....	1300
1898	Clover	.....	1320
1899	Clover	.....	3380
1900	Clover	.....	720
1901	Clover	.....	1220
1902	Clover	.....	2850
1903	Clover (1)	Abandoned	
1904	Clover	Abandoned	
1905	Clover	Abandoned	
1906	Clover	Abandoned	
1907	Clover	Abandoned	
1908	Clover	Abandoned	
1909	Clover	.....	Omitted
1910	Oats	13.80	1606
1911	Clover	.....	Omitted
1912	Wheat	19.61	2151
1913	Cowpeas	.....	1547
1914	Cowpeas	.....	4056
1915	Cowpeas	.....	4270
1916	Cowpeas	.....	5684
1917	Cowpeas	.....	3514
1918	Cowpeas	.....	4760
Average Clover		.....	2430
Average Cowpeas		.....	3972

(1) Plot not used for experiment during this period.

PLOT NO. 8

6-YEAR ROTATION: CORN, OATS, WHEAT, CLOVER, TIMOTHY, TIMOTHY

*Manured Annually

Year	Crop	Yield	
		Grain	Forage
1889	Clover	.....	3450
1890	Clover	.....	4010
1891	Timothy	.....	7350
1892	Timothy	.....	5400
1893	Corn	38.57	3940
1894	Oats	42.50	1320
1895	Clover	.....	5480
1896	Wheat	31.33	3820
1897	Timothy	.....	4250
1898	Timothy	.....	4960
1899	Corn	45.20	2200
1900	Oats	53.60	2285
1901	Clover	.....	1030
1902	Wheat	29.80	6010
1903	Wheat	15.27	2983
1904	(1)		
Average Corn		41.9	3070
Average Oats		48.0	1802
Average Wheat		25.5	4271
Average Clover		.....	3492
Average Timothy		.....	5490

* 6 tons manure per acre annually, 1880-1903. Plot discontinued after 1903.

(1) Plot abandoned to give room for a street.

PLOT NO. 9

WHEAT CONTINUOUSLY

No Manure or Fertilizer

Year	Crop	Yield	
		Grain	Forage
1889	Wheat.....	8.17	935
1890	Wheat.....	.....	Omitted
1891	Wheat.....	24.58	2725
1892	Wheat.....	6.17	1610
1893	Wheat.....	0.00	0000
1894	Wheat.....	18.00	1880
1895	Wheat.....	22.00	2880
1896	Wheat.....	2.83	390
1897	Wheat.....	1.66	210
1898	Wheat.....	2.70	720
1899	Wheat.....	2.70	318
1900	Wheat.....	10.70	1360
1901	Wheat.....	15.60	1855
1902	Wheat.....	28.60	3935
1903	Wheat.....	11.48	3276
1904	Wheat.....	.....	Omitted
1905	Wheat.....	.....	Omitted
1906	Wheat.....	5.85	758
1907	Wheat.....	7.05	914
1908	Wheat.....	7.10	920
1909	Wheat.....	0.00	000
1910	Wheat.....	10.51	1444
1911	Wheat.....	4.98	486
1912	Wheat.....	1.30	228
1913	Wheat.....	8.83	913
1914	Wheat.....	20.07	1922
1915	Wheat.....	1.98	399
1916	Wheat.....	8.40	1197
1917	Wheat.....	.20	112
1918	Wheat.....	21.00	2114
Average Wheat.....		9.5	1241

PLOT NO. 10

WHEAT CONTINUOUSLY

*Manured Annually

Year	Crop	Yield	
		Grain	Forage
1889	Wheat.....	15.00	1580
1890	Wheat.....	.....	Omitted
1891	Wheat.....	31.25	4475
1892	Wheat.....	14.00	2920
1893	Wheat.....	0.00	0000
1894	Wheat.....	34.83	2630
1895	Wheat.....	40.67	5160
1896	Wheat.....	20.00	1240
1897	Wheat.....	6.10	935
1898	Wheat.....	5.25	2025
1899	Wheat.....	15.80	1690
1900	Wheat.....	21.50	2790
1901	Wheat.....	25.20	3410
1902	Wheat.....	27.10	4830
1903	Wheat.....	16.02	3100
1904	Wheat.....	.....	Omitted
1905	Wheat.....	15.38	1933
1906	Wheat.....	8.66	1122
1907	Wheat.....	10.80	1400
1908	Wheat.....	16.10	2087
1909	Wheat.....	15.20	1970
1910	Wheat.....	6.21	3234
1911	Wheat.....	10.30	1538
1912	Wheat.....	12.46	2204
1913	Wheat.....	16.90	3205
1914	Wheat.....	26.37	3707
1915	Wheat.....	18.66	1988
1916	Wheat.....	10.7	2114
1917	Wheat.....	10.9	1820
1918	Wheat.....	30.33	3402
Average Wheat.....		17.2	2447

*6 tons manure per acre annually, 1889-1903; 7.8 tons, 1903-1913; 6 tons, 1914-1918.

PLOT NO. 11

6-YEAR ROTATION: CORN, OATS, WHEAT, CLOVER, TIMOTHY, TIMOTHY

*Manured Annually

Year	Crop	Yield	
		Grain	Forage
1889	Wheat	16.17	1800
1890	Timothy	.....	3120
1891	Timothy	.....	6860
1892	Corn	37.93	1420
1893	Oats	27.81	1750
1894	Clover	.....	4580
1895	Wheat	44.00	5560
1896	Clover	.....	1280
1897	Timothy	.....	6700
1898	Corn	27.00	1380
1899	Oats	36.70	2525
1900	Clover	.....	7080
1901	Wheat	43.30	6650
1902	Timothy	.....	2750
1903	Omitted.		
1904	Corn	43.83	1820
1905	Oats	28.03	2243
1906	Cowpeas	.....	1690
1907	Wheat	26.43	3426
1908	Timothy	.....	7398
1909	Timothy	.....	8320
1910	Corn	51.60	3146
1911	Oats	18.50	1072
1912	Wheat	22.48	3129
1913	Clover	.....	4303
Average Corn		40.1	1941
Average Oats		27.8	1898
Average Wheat		30.5	4113
Average Clover		.....	4311
Average Timothy		.....	5858

* 6 tons manure per acre annually, 1889-1903; 7.8 tons, 1904-1913.

PLOT NO. 12

6-YEAR ROTATION: CORN, OATS, WHEAT, CLOVER, TIMOTHY, TIMOTHY

*Manured Annually

Year	Crop	Yield	
		Grain	Forage
1889	Timothy	.....	1500
1890	Timothy	.....	4690
1891	Corn	41.50	2470
1892	Oats	00.00	0000
1893	Clover	.....	5900
1894	Wheat	43.50	4090
1895	Timothy	.....	4300
1896	Clover	.....	6080
1897	Corn	64.80	3920
1898	Oats	8.00	1104
1899	Clover	.....	2380
1900	Wheat	28.80	4030
1901	Timothy	.....	0000
1902	Timothy	.....	1750
1903	Omitted.		
1904	Oats	17.47	1398
1905	Wheat	.....	Omitted
1906	Omitted.		
1907	Timothy	.....	3250
1908	Timothy	.....	7840
1909	Corn	31.94	3040
1910	Oats	34.10	2170
1911	Oats	17.40	980
1912	Wheat	23.29	3332
1913	Clover	.....	5538
Average Corn		46.1	3143
Average Oats		15.4	1130
Average Wheat		31.9	3817
Average Clover		.....	4974
Average Timothy		.....	3333

* 6 tons manure per acre annually, 1889-1903; 7.8 tons, 1904-1913.

PLOT NO. 13

6-YEAR ROTATION: CORN, OATS, WHEAT, CLOVER, TIMOTHY, TIMOTHY

No Manure or Fertilizer

Year	Crop	Yield	
		Grain	Forage
1889	Wheat	6.50	820
1890	Timothy	.....	1790
1891	Timothy	.....	3920
1892	Corn	25.71	1300
1893	Oats	21.88	3160
1894	Clover	.....	1230
1895	Wheat	33.00	3170
1896	Timothy	.....	1900
1897	Timothy	.....	4600
1898	Corn	25.10	1340
1899	Oats	32.80	1290
1900	Clover	.....	3780
1901	Wheat	39.30	3190
1902	Timothy	.....	130
1903	Corn	85.42	4290
1904	Corn	54.20	2145
1905	Oats	16.65	1330
1906	Cowpeas	.....	1040
1907	Wheat	10.80	1404
1908	Timothy	.....	3536
1909	Timothy	.....	2820
1910	Corn	39.40	962
1911	Oats	13.82	636
1912	Wheat	13.97	1359
1913	Clover	.....	1508
1914	Timothy	.....	124
1915	Timothy	.....	3192
1916	Corn	19.00	1680
1917	Oats	51.10	2184
1918	Wheat	16.80	1540
Average Corn		41.5	1899
Average Oats		27.2	1720
Average Wheat		20.1	1914
Average Clover		.....	2173
Average Timothy		.....	2446

PLOT NO. 14

6-YEAR ROTATION: CORN, OATS, WHEAT, CLOVER, TIMOTHY, TIMOTHY

*Manured Annually

Year	Crop	Yield	
		Grain	Forage
1889	Oats	29.53	1945
1890	Clover	.....	0000
1891	Wheat	27.00	3140
1892	Timothy	.....	4280
1893	Timothy	.....	4340
1894	Corn	12.00	3440
1895	Oats	25.00	1620
1896	Clover	.....	5580
1897	Wheat	37.67	4640
1898	Timothy	.....	5280
1899	Timothy	.....	5040
1900	Corn	41.40	2100
1901	Oats	2.30	545
1902	Clover	.....	2100
1903	Omitted.		
1904	Timothy	.....	Omitted
1905	Omitted	.....	.....
1906	Corn	.....	Omitted
1907	Oats	34.93	2795
1908	Clover	.....	0000
1909	Wheat	16.50	2138
1910	Corn	52.90	2302
1911	Oats	23.98	1220
1912	Wheat	21.99	3419
1913	Clover	.....	5018
Average Corn		35.4	2614
Average Oats		23.1	1625
Average Wheat		25.8	3334
Average Clover		.....	2540
Average Timothy		.....	4735

*6 tons manure per acre annually, 1889-1903; 7.8 tons, 1904-1913.

PLOT NO. 15

OATS CONTINUOUSLY

*Manured Annually

Year	Crop	Yield	
		Grain	Forage
1889	Oats.....	36.88	2507
1890	Oats.....	.....	Omitted
1891	Oats.....	25.94	3970
1892	Oats.....	0.00	0000
1893	Oats.....	30.63	1480
1894	Oats.....	30.31	1390
1895	Oats.....	42.19	2750
1896	Timothy.....	.....	4400
1897	Oats.....	36.00	3000
1898	Oats.....	4.70	390
1899	Oats.....	27.30	1285
1900	Oats.....	49.80	2415
1901	Oats.....	2.00	430
1902	Oats.....	15.10	1065
1903	Oats.....	Omitted	Omitted
1904	Oats.....	31.30	2504
1905	Oats.....	19.09	1527
1906	Oats.....	34.13	2720
1907	Oats.....	37.37	2990
1908	Oats.....	29.04	2323
1909	Oats.....	15.84	1267
1910	Oats.....	29.74	2584
1911	Oats.....	26.10	1460
1912	Oats.....	32.44	2288
1913	Oats.....	9.55	1144
1914	Oats.....	5.28	1033
1915	Oats.....	35.81	2338
1916	Oats.....	30.2	2296
1917	Oats.....	65.1	3122
1918	Oats.....	36.08	1771
Average Oats.....		27.3	1928

* 6 tons manure per acre annually, 1889-1903; 7.8 tons, 1904-1913; 6 tons, 1914-1918.

PLOT NO. 16

OATS CONTINUOUSLY

No Manure or Fertilizer

Year	Crop	Yield	
		Grain	Forage
1889	Oats.....	27.35	2207
1890	Oats.....	Omitted	Omitted
1891	Oats.....	18.44	3540
1892	Oats.....	00.00	0000
1893	Oats.....	17.82	840
1894	Oats.....	30.94	1270
1895	Oats.....	28.13	1080
1896	Timothy.....	.....	2850
1897	Oats.....	11.00	450
1898	Oats.....	2.50	260
1899	Oats.....	13.40	550
1900	Oats.....	24.80	1105
1901	Oats.....	1.10	190
1902	Oats.....	20.80	785
1903	Oats.....	Omitted	Omitted
1904	Oats.....	7.30	584
1905	Oats.....	7.31	585
1906	Oats.....	17.06	1365
1907	Oats.....	21.93	1754
1908	Oats.....	10.16	813
1909	Oats.....	12.19	994
1910	Oats.....	9.03	542
1911	Oats.....	5.01	320
1912	Oats.....	29.34	1248
1913	Oats.....	3.86	338
1914	Oats.....	4.06	432
1915	Oats.....	30.62	1722
1916	Oats.....	29.00	1036
1917	Oats.....	53.70	2044
1918	Oats.....	19.90	772
Average Oats.....		16.9	1099

PLOT NO. 17

CORN CONTINUOUSLY

No Manure or Fertilizer

Year	Crop	Yield	
		Grain	Forage
1889	Corn.....	27.14	3070
1890	Corn.....	41.14	2190
1891	Corn.....	32.07	1870
1892	Corn.....	42.14	3550
1893	Corn.....	24.86	3660
1894	Corn.....	17.14	2160
1895	Corn.....	31.43	2300
1896	Corn.....	21.00	1590
1897	Corn.....	22.90	1900
1898	Corn.....	23.90	1340
1899	Corn.....	19.40	1200
1900	Corn.....	16.80	1200
1901	Corn.....	5.70	750
1902	Corn.....	38.00	1800
1903	Corn.....	29.53	1954
1904	Corn.....	17.10	2275
1905	Corn.....	11.88	1612
1906	Corn.....	Omitted	Omitted
1907	Corn.....	11.70	1196
1908	Corn.....	4.45	3470
1909	Corn.....	1.30	1886
1910	Corn.....	1.85	754
1911	Corn.....	13.18	1677
1912	Corn.....	27.01	1469
1913	Corn.....	6.96	2730
1914	Corn.....	28.78	2678
1915	Corn.....	38.00	2744
1916	Corn.....	7.4	1988
1917	Corn.....	27.59	1610
1918	Corn.....	14.4	2884
Average Corn.....		20.9	2052

PLOT NO. 18

CORN CONTINUOUSLY

*Manured Annually

Year	Crop	Yield	
		Grain	Forage
1889	Corn.....	34.86	4020
1890	Corn.....	60.71	3350
1891	Corn.....	36.36	2990
1892	Corn.....	51.43	2200
1893	Corn.....	34.00	3340
1894	Corn.....	30.29	3040
1895	Corn.....	64.31	3900
1896	Corn.....	46.42	2890
1897	Corn.....	47.20	2700
1898	Corn.....	25.60	1380
1899	Corn.....	31.90	2000
1900	Corn.....	28.60	1500
1901	Corn.....	11.30	1450
1902	Corn.....	79.40	3060
1903	Corn.....	55.54	2808
1904	Corn.....	13.37	1885
1905	Corn.....	64.25	3652
1906	Corn.....	.....	Omitted
1907	Corn.....	33.42	1768
1908	Corn.....	11.70	3992
1909	Corn.....	16.57	2938
1910	Corn.....	6.50	1418
1911	Corn.....	25.07	2690
1912	Corn.....	30.82	1625
1913	Corn.....	19.22	3870
1914	Corn.....	33.89	4079
1915	Corn.....	45.70	3332
1916	Corn.....	14.6	3066
1917	Corn.....	35.59	3668
1918	Corn.....	22.4	5166
Average Corn.....		34.9	2889

*6 tons manure per acre annually, 1889-1903; 7.8 tons, 1904-1913; 6 tons, 1914-1918.

PLOT NO. 19

6-YEAR ROTATION: CORN, OATS, WHEAT, CLOVER, TIMOTHY, TIMOTHY

*Manured Annually

Year	Crop	Yield	
		Grain	Forage
1889	Corn.....	28.43	3340
1890	Oats.....	Omitted	Omitted
1891	Clover.....	.....	3020
1892	Wheat.....	14.83	4590
1893	Timothy.....	.....	3280
1894	Timothy.....	.....	4880
1895	Corn.....	80.00	4700
1896	Timothy.....	.....	5000
1897	Clover.....	.....	5400
1898	Wheat.....	9.50	2650
1899	Timothy.....	.....	4700
1900	Timothy.....	.....	5500
1901	Corn.....	15.80	1775
1902	Oats.....	Omitted	2100
1903	Omitted.		
1904	Wheat.....	Omitted	Omitted
1905	Omitted.		
1906	Timothy.....	.....	0000
1907	Corn.....	53.48	2327
1908	Oats.....	26.41	2113
1909	Cowpeas.....	.....	4784
1910	Wheat.....	19.17	4134
1911	Oats.....	22.45	940
1912	Wheat.....	12.86	1930
1913	Clover.....	.....	5109
Average Corn.....		44.4	3035
Average Oats.....		24.4	1718
Average Wheat.....		14.1	3326
Average Clover.....		.....	4510
Average Timothy.....		.....	3893

*6 tons manure per acre annually, 1889-1903; 7.8 tons 1904-1913.

PLOT NO. 20

6-YEAR ROTATION: CORN, OATS, WHEAT, CLOVER, TIMOTHY, TIMOTHY

*Manured Annually

Year	Crop	Yield	
		Grain	Forage
1889	Timothy.....	.....	2950
1890	Timothy.....	.....	5040
1891	Corn.....	41.71	2960
1892	Oats.....	0.00	0000
1893	Clover.....	.....	4540
1894	Wheat.....	41.33	4070
1895	Timothy.....	.....	4400
1896	Clover.....	.....	5700
1897	Corn.....	64.80	3750
1898	Oats.....	4.70	910
1899	Clover.....	.....	2400
1900	Wheat.....	33.70	3740
1901	Timothy.....	.....	0000
1902	Timothy.....	.....	2000
1903	Corn.....	78.74	4472
1904	Oats.....	25.20	2016
1905	Omitted.		
1906	Wheat.....	18.83	2440
1907	Timothy.....	.....	4160
1908	Timothy.....	.....	7240
1909	Corn.....	28.79	2510
1910	Oats.....	44.05	2978
1911	Oats.....	17.88	800
1912	Wheat.....	16.09	2875
1913	Clover.....	.....	4810
1914	Timothy.....	.....	766
1915	Timothy.....	.....	6818
1916	Corn.....	28.00	4060
1917	Oats.....	60.50	2876
1918	Wheat.....	34.30	3990
Average Corn.....		48.4	3550
Average Oats.....		25.4	1597
Average Wheat.....		28.9	3423
Average Clover.....		.....	4362
Average Timothy.....		.....	3708

*6 tons manure per acre annually, 1889-1903; 7.8 tons, 1904-1913; 6 tons, 1914-1918.

PLOT NO. 21

WHEAT CONTINUOUSLY

*Manured Annually

Year	Crop	Yield	
		Grain	Forage
1889	Wheat.....	11.83	1910
1890	Wheat.....	Omitted	Omitted
1891	Wheat.....	30.83	5370
1892	Wheat.....	24.00	3360
1893	Wheat.....	00.00	0000
1894	Wheat.....	39.17	3060
1895	Wheat.....	43.33	4800
1896	Wheat.....	20.17	2950
1897	Wheat.....	8.40	1195
1898	Wheat.....	6.30	1580
1899	Wheat.....	15.80	1590
1900	Wheat.....	23.50	3330
1901	Wheat.....	24.12	3420
1902	Wheat.....	32.60	6790
1903	Wheat.....	6.82	2450
1904	Wheat.....	Omitted	Omitted
1905	Wneat.....	15.60	2022
1906	Wheat.....	7.15	927
1907	Wheat.....	24.05	3117
1908	Wheat.....	23.90	3097
1909	Wheat.....	11.70	1516
1910	Wheat.....	Omitted	Omitted
1911	Wheat.....	30.55	3472
1912	Wheat.....	12.07	2384
1913	Wheat.....	17.44	3387
Average Wheat.....		19.5	2806

* 6 tons manure per acre annually, 1889-1903; 7.8 tons, 1904-1913.

PLOT NO. 22

TIMOTHY CONTINUOUSLY

*Manured Annually

Year	Crop	Yield	
		Grain	Forage
1889	Timothy.....	.....	2100
1890	Timothy.....	.....	5790
1891	Timothy.....	.....	7600
1892	Timothy.....	.....	6960
1893	Timothy.....	.....	6200
1894	Timothy.....	.....	4640
1895	Timothy.....	.....	6500
1896	Timothy.....	.....	5840
1897	Timothy.....	.....	6100
1898	Timothy.....	.....	5980
1899	Timothy.....	.....	4760
1900	Timothy.....	.....	4800
1901	Timothy.....	.....	2400
1902	Timothy.....	.....	5700
1903	Timothy.....	.....	Omitted
1904	Timothy.....	.....	Omitted
1905	Timothy.....	.....	Omitted
1906	Timothy.....	.....	2275
1907	Timothy.....	.....	2730
1908	Timothy.....	.....	7812
1909	Timothy.....	.....	6032
1910	Timothy.....	.....	4160
1911	Timothy.....	.....	2600
1912	Timothy.....	.....	6110
1913	Timothy.....	.....	3042
1914	Timothy.....	.....	889
1915	Timothy.....	.....	6888
1916	Timothy.....	.....	6650
1917	Timothy.....	.....	5586
1918	Timothy.....	.....	2240
Average Timothy.....		.....	4902

* 6 tons manure per acre annually, 1889-1903; 7.8 tons, 1904-1913; 6 tons, 1914-1918.

PLOT NO. 23

TIMOTHY CONTINUOUSLY

No Manure or Fertilizer

Year	Crop	Yield	
		Grain	Forage
1889	Timothy.....	.....	1600
1890	Timothy.....	.....	2290
1891	Timothy.....	.....	4760
1892	Timothy.....	.....	4000
1893	Timothy.....	.....	3820
1894	Timothy.....	.....	3880
1895	Timothy.....	.....	5440
1896	Timothy.....	.....	2480
1897	Timothy.....	.....	2400
1898	Timothy.....	.....	3000
1899	Timothy.....	.....	2260
1900	Timothy.....	.....	2500
1901	Timothy.....	.....	1150
1902	Timothy.....	.....	4500
1903	Timothy.....	.....	Omitted
1904	Timothy.....	.....	Omitted
1905	Timothy.....	.....	Omitted
1906	Timothy.....	.....	1820
1907	Timothy.....	.....	0000
1908	Timothy.....	.....	3654
1909	Timothy.....	.....	2146
1910	Timothy.....	.....	2340
1911	Timothy.....	.....	0000
1912	Timothy.....	.....	4550
1913	Timothy.....	.....	1339
1914	Timothy.....	.....	546
1915	Timothy.....	.....	3276
1916	Timothy.....	.....	3220
1917	Timothy.....	.....	2142
1918	Timothy.....	.....	490
Average Timothy.....		.....	2577

PLOT NO. 24

WHEAT CONTINUOUSLY

*Manured Annually

Year	Crop	Yield	
		Grain	Forage
1889	Wheat.....	17.00	1780
1890	Wheat.....	Omitted	Omitted
1891	Wheat.....	30.60	2065
1892	Wheat.....	13.67	3540
1893	Wheat.....	00.00	0000
1894	Wheat.....	31.17	3170
1895	Wheat.....	39.17	5950
1896	Wheat.....	18.66	2100
1897	Wheat.....	8.20	1060
1898	Wheat.....	4.80	1390
1899	Wheat.....	12.00	1140
1900	Wheat.....	19.30	2920
1901	Wheat.....	23.60	1485
1902	Wheat.....	30.10	4840
1903	Wheat.....	7.47	2440
1904	Wheat.....	Omitted	Omitted
1905	Wheat.....	15.60	2022
1906	Wheat.....	11.83	1533
1907	Wheat.....	23.07	2980
1908	Wheat.....	24.70	3320
1909	Wheat.....	13.80	1788
1910	Wheat.....	Omitted	Omitted
1911	Wheat.....	28.55	3318
1912	Wheat.....	10.72	1970
1913	Wheat.....	17.33	2743
Average Wheat.....		18.2	2443

*6 tons manure per acre annually, 1889–1903; 7.8 tons, 1904-1913.

PLOT NO. 25

3-YEAR ROTATION: CORN, WHEAT, CLOVER

*Manured Annually

Year	Crop	Yield	
		Grain	Forage
1889	Corn.....	37.71	3310
1890	Clover.....	.....	0000
1891	Wheat.....	17.00	1690
1892	Corn.....	52.00	5400
1893	Clover.....	.....	5880
1894	Wheat.....	39.67	2500
1895	Corn.....	77.14	3800
1896	Clover.....	.....	2040
1897	Wheat.....	20.17	2490
1898	Corn.....	25.20	1400
1899	Clover.....	.....	3240
1900	Wheat.....	23.50	3390
1901	Corn.....	8.20	1050
1902	Clover.....	.....	Omitted
1903	Omitted.		
1904	Corn.....	38.70	1534
1905	Omitted.		
1906	Wheat.....	17.11	2217
1907	Corn.....	56.64	2080
1908	Wheat.....	29.40	3910
1909	Cowpeas.....	.....	4446
1910	Corn.....	28.04	1600
1911	Wheat.....	32.12	3286
1912	Cowpeas.....	.....	7410
1913	Corn.....	25.07	6669
1914	Wheat.....	35.67	4074
1915	Cowpeas.....	.....	6146
1916	Corn.....	24.80	3038
1917	Wheat.....	31.00	4312
1918	Clover.....	.....	5908
Average Corn.....		37.3	2988
Average Wheat.....		27.3	3096
Average Clover.....		.....	3414

* 6 tons manure per acre annually, 1889-1903; 7.8 tons 1904-1913; 6 tons, 1913-1918.

PLOT NO. 26

3-YEAR ROTATION: CORN, WHEAT, CLOVER

*Manured Annually

Year	Crop	Yield	
		Grain	Forage
1889	Clover.....	.....	2300
1890	Clover.....	.....	5320
1891	Corn.....	41.71	2450
1892	Clover.....	.....	0000
1893	Wheat.....	9.00	1480
1894	Corn.....	33.71	3720
1895	Clover.....	.....	4600
1896	Wheat.....	31.50	4550
1897	Corn.....	45.40	2660
1898	Clover.....	Omitted	Omitted
1899	Wheat.....	16.60	1620
1900	Corn.....	47.90	2320
1901	Clover.....	.....	0000
1902	Wheat.....	25.50	6520
1903	Corn.....	82.08	3900
1904	Clover.....	.....	Omitted
1905	Wheat.....	22.31	2891
1906	Corn.....	Omitted	Omitted
1907	Clover.....	.....	0000
1908	Clover.....	.....	5450
1909	Corn.....	22.29	1833
1910	Wheat.....	9.64	2818
1911	Wheat.....	31.80	3424
1912	Cowpeas.....	.....	8710
1913	Corn.....	24.14	7176
Average Corn.....		42.5	3437
Average Wheat.....		20.9	3329
Average Clover.....		.....	2524

* 6 tons manure per acre annually, 1889-1903; 7.8 tons, 1904-1913.

PLOT NO. 27

3-YEAR ROTATION: CORN, WHEAT, CLOVER

No Manure or Fertilizer

Year	Crop	Yield	
		Grain	Forage
1889	Wheat.....	14.92	1505
1890	Corn.....	28.36	1990
1891	Clover.....	.....	Omitted
1892	Wheat.....	9.17	1450
1893	Corn.....	24.29	2500
1894	Clover.....	.....	1350
1895	Wheat.....	27.50	2400
1896	Corn.....	34.85	2020
1897	Clover.....	.....	2660
1898	Wheat.....	5.00	1910
1899	Corn.....	25.50	1320
1900	Clover.....	.....	1800
1901	Wheat.....	23.30	2960
1902	Corn.....	65.30	1850
1903	Omitted.		
1904	Wheat.....	Omitted	Omitted
1905	Corn.....	50.70	2470
1906	Cowpeas.....	.....	1300
1907	Corn.....	47.17	2665
1908	Wheat.....	6.90	1294
1909	Cowpeas.....	.....	2054
1910	Corn.....	16.57	1522
1911	Wheat.....	11.48	1170
1912	Cowpeas.....	.....	4450
1913	Corn.....	13.93	5837
1914	Wheat.....	18.09	1452
1915	Cowpeas.....	.....	2688
1916	Corn.....	19.60	2604
1917	Wheat.....	13.50	1316
1918	Clover.....	.....	1862
Average Corn.....		32.6	2478
Average Wheat.....		14.4	1717
Average Clover.....		.....	1918

PLOT NO. 28

3-YEAR ROTATION: CORN, WHEAT, CLOVER

*Manured Annually

Year	Crop	Yield	
		Grain	Forage
1889	Wheat.....	18.42	2445
1890	Corn.....	45.79	2220
1891	Clover.....	.....	Omitted
1892	Wheat.....	24.17	4200
1893	Corn.....	34.60	3500
1894	Clover.....	.....	3500
1895	Wheat.....	42.33	4460
1896	Corn.....	51.42	2720
1897	Clover.....	.....	7440
1898	Wheat.....	15.70	2720
1899	Corn.....	37.90	1860
1900	Clover.....	.....	4600
1901	Wheat.....	34.50	4500
1902	Corn.....	88.60	1850
1903	Omitted.		
1904	Wheat.....	Omitted	Omitted
1905	Corn.....	77.62	3315
1906	Cowpeas.....	.....	1820
1907	Corn.....	65.92	3679
1908	Wheat.....	29.20	3784
1909	Cowpeas.....	.....	3042
1910	Corn.....	32.69	2626
1911	Wheat.....	33.58	3586
1912	Cowpeas.....	.....	7150
1913	Corn.....	24.70	7059
Average Corn.....		51.0	3203
Average Wheat.....		28.3	3671
Average Clover.....		.....	5180

* 6 tons manure per acre annually, 1889–1903; 7.8 tons, 1903-1913.

PLOT NO. 29 (1)

WHEAT CONTINUOUSLY

No Manure or Fertilizer

Year	Crop	Yield	
		Grain	Forage
1889	Wheat.....	25.42	3205
1890	Wheat.....	Omitted	Omitted
1891	Wheat.....	33.83	4450
1892	Wheat.....	23.50	2950
1893	Wheat.....	00.00	0000
1894	Wheat.....	29.75	3840
1895	Wheat.....	36.00	3890
1896	Wheat.....	9.83	1230
1897	Wheat.....	8.33	650
1898	Wheat.....	3.16	890
1899	Wheat.....	3.00	300
1900	Wheat.....	10.50	1230
1901	Wheat.....	21.00	940
1902	Wheat.....	31.50	2920
1903	Wheat.....	10.82	2115
1904	Wheat.....	Omitted	Omitted
1905	Wheat.....	19.28	2499
1906	Wheat.....	8.01	1038
1907	Wheat.....	9.53	1235
1908	Wheat.....	16.40	2125
Average Wheat.....		16.7	1973

* No manure, 1889-1907. 7.8 tons manure 1908-1913.

(1) Plot 29 omitted from general average because of a change of plan after 1908.

PLOT NO. 30

WHEAT CONTINUOUSLY

*Manured Annually

Year	Crop	Yield	
		Grain	Forage
1889	Wheat.....	20.92	2045
1890	Wheat.....	Omitted	Omitted
1891	Wheat.....	31.92	4355
1892	Wheat.....	26.17	3210
1893	Wheat.....	00.00	0000
1894	Wheat.....	33.58	3085
1895	Wheat.....	41.33	3970
1896	Wheat.....	26.00	2980
1897	Wheat.....	14.80	181
1898	Wheat.....	8.50	2210
1899	Wheat.....	15.70	1580
1900	Wheat.....	16.70	2260
1901	Wheat.....	28.50	3510
1902	Wheat.....	25.80	5430
1903	Wheat.....	7.36	2710
1904	Wheat.....	Omitted	Omitted
1905	Wheat.....	29.66	3844
1906	Wheat.....	11.26	1459
1907	Wheat.....	11.37	1474
1908	Wheat.....	19.10	2475
1909	Wheat.....	10.40	1348
1910	Wheat.....	Omitted	Omitted
1911	Wheat.....	18.35	2490
1912	Wheat.....	12.02	2763
1913	Wheat.....	22.53	3510
Average Wheat.....		19.6	2586

* 6 tons manure per acre annually, 1889-1903; 7.8 tons, 1904-1913.

PLOT NO. 31

2-YEAR ROTATION: WHEAT, CLOVER

*Manured Annually.

Year	Crop	Yield	
		Grain	Forage
1889	Wheat.....	21.33	2030
1890	Clover.....	.....	3200
1891	Wheat.....	31.35	4935
1892	Clover.....	.....	4760
1893	Wheat.....	9.33	1860
1894	Clover.....	.....	5380
1895	Wheat.....	43.33	3940
1896	Clover.....	.....	2200
1897	Wheat.....	30.33	3680
1898	Clover.....	.....	5260
1899	Wheat.....	14.80	1712
1900	Clover.....	.....	7400
1901	Wheat.....	38.20	5950
1902	Clover.....	.....	1450
1903	Omitted.		
1904	Omitted.		
1905	Wheat.....	11.05	1432
1906	Cowpeas.....	.....	2470
1907	Wheat.....	24.24	3141
1908	Clover.....	.....	9932
1909	Wheat.....	12.10	1568
1910	Cowpeas.....	.....	5408
1911	Wheat.....	32.55	3404
1912	Cowpeas.....	.....	4550
1913	Wheat.....	27.79	3039
1914	Cowpeas.....	.....	5135
1915	Wheat.....	25.08	3955
1916	Cowpeas.....	.....	7308
1917	Wheat.....	27.40	3520
1918	Clover.....	.....	6006
Average Wheat.....		24.9	3155
Average Clover.....		.....	5065
Average Cowpeas.....		.....	4974

* 6 tons manure per acre annually, 1889-1903; 7.8 tons, 1903-1913; 6 tons, 1914-1918.

PLOT NO. 32

2-YEAR ROTATION: WHEAT, CLOVER

*Manured Annually.

Year	Crop	Yield	
		Grain	Forage
1889	Clover.....	.....	5700
1890	Clover.....	.....	5100
1891	Clover.....	.....	5440
1892	Wheat.....	22.58	3670
1893	Clover.....	.....	5000
1894	Wheat.....	37.92	2885
1895	Clover.....	.....	5300
1896	Wheat.....	34.33	5340
1897	Clover.....	.....	3850
1898	Wheat.....	11.00	2400
1899	Clover.....	.....	3500
1900	Wheat.....	18.20	2810
1901	Clover.....	.....	2480
1902	Clover.....	Omitted.	
1903	Wheat.....	3.36	2301
1904	Wheat.....	Omitted.	
1905	Omitted.		
1906	Wheat.....	17.11	2217
1907	Clover.....	.....	4030
1908	Wheat.....	19.50	2527
1909	Cowpeas.....	.....	3276
1910	Wheat.....	Omitted.	
1911	Wheat.....	22.27	2798
1912	Cowpeas.....	.....	4810
1913	Wheat.....	28.17	4225
Average Wheat.....		21.44	3117
Average Clover.....		.....	4489
Average Cowpeas.....		.....	4043

* 6 tons manure per acre annually, 1889-1903; 7.8 tons, 1904-1913.

PLOT NO. 33

2-YEAR ROTATION: WHEAT, CLOVER

No Manure or Fertilizer.

Year	Crop	Yield	
		Grain	Forage
1889	Wheat	23.67	2270
1890	Clover	.....	4600
1891	Wheat	33.33	5300
1892	Clover	.....	3800
1893	Wheat	8.33	1780
1894	Clover	.....	2360
1895	Wheat	34.67	4880
1896	Clover	.....	1320
1897	Wheat	12.50	2250
1898	Clover	.....	3180
1899	Wheat	2.70	438
1900	Clover	.....	4320
1901	Wheat	30.90	3545
1902	Clover	.....	1100
1903	Omitted.		
1904	Clover	Omitted.	
1905	Wheat	9.96	1290
1906	Cowpeas	.....	1950
1907	Wheat	12.78	1656
1908	Clover	.....	4278
1909	Wheat	14.30	1853
1910	Cowpeas	.....	5252
1911	Wheat	16.90	2528
1912	Cowpeas	.....	3250
1913	Wheat	25.68	2717
1914	Cowpeas	.....	6031
1915	Wheat	11.66	2156
1916	Cowpeas	.....	5684
1917	Wheat	20.7	1512
1918	Clover	.....	1512
Average Wheat		18.4	2405
Average Clover		.....	2974
Average Cowpeas		.....	4439

PLOT NO. 34

4-YEAR ROTATION: CORN, OATS, WHEAT, CLOVER

*Manured Annually.

Year	Crop	Yield	
		Grain	Forage
1889	Corn	42.00	3100
1890	Oats	Omitted.	
1891	Clover	.....	3000
1892	Wheat	9.33	4200
1893	Corn	23.71	3940
1894	Oats	41.25	1900
1895	Clover	.....	4600
1896	Clover	.....	4600
1897	Corn	58.60	3060
1898	Oats	4.10	469
1899	Clover	.....	2600
1900	Wheat	17.80	3190
1901	Corn	3.00	880
1902	Oats	6.20	1300
1903	Omitted.		
1904	Wheat	Omitted.	
1905	Corn	75.02	3172
1906	Oats	34.12	2730
1907	Clover	.....	5902
1908	Wheat	16.10	2287
1909	Corn	36.40	3068
1910	Oats	27.40	2119
1911	Corn	32.03	4901
1912	Oats	40.83	2451
1913	Wheat	28.33	4215
1914	Cowpeas	.....	7033
1915	Corn	55.62	4634
1916	Oats	42.90	2212
1917	Wheat	39.4	5726
1918	Clover	.....	4578
Average Corn		40.8	3344
Average Oats		28.2	1883
Average Wheat		22.2	3923
Average Clover		.....	4213

* 6 tons manure per acre annually, 1889-1903; 7.8 tons, 1904-1913; 6 tons, 1914-1918.

PLOT NO. 35

4-YEAR ROTATION: CORN, OATS, WHEAT, CLOVER

*Manured Annually.

Year	Crop	Yield	
		Grain	Forage
1889	Oats.....	28.44	1975
1890	Clover.....	.....	3550
1891	Wheat.....	19.58	1825
1892	Corn.....	40.00	1100
1893	Oats.....	29.38	2350
1894	Clover.....	.....	4490
1895	Wehat.....	35.83	5050
1896	Corn.....	60.86	2340
1897	Oats.....	37.50	3300
1898	Clover.....	.....	4700
1899	Wheat.....	24.30	3020
1900	Corn.....	42.10	2000
1901	Oats.....	3.00	500
1902	Clover.....	.....	2000
1903	Corn.....	Omitted.	
1904	Corn.....	47.30	1638
1905	Oats.....	28.03	2242
1906	Cowpeas.....	.....	1820
1907	Wheat.....	17.44	2260
1908	Corn.....	48.50	4400
1909	Oats.....	16.25	1300
1910	Clover.....	.....	1040
1911	Corn.....	37.30	5603
1912	Oats.....	51.59	2932
1913	Wheat.....	25.13	3751
Average Corn.....		46.0	2847
Average Oats.....		27.7	2085
Average Wheat.....		24.4	3181
Average Clover.....		.....	5028

*6 tons manure per acre annually, 1889-1903; 7.8 tons, 1904-1913.

PLOT NO. 36

WHEAT CONTINUOUSLY

*Manured Annually.

Year	Crop	Yield	
		Grain	Forage
1889	Wheat.....	23.00	2070
1890	Wheat.....	Omitted.	
1891	Wheat.....	27.33	4570
1892	Wheat.....	29.83	3870
1893	Wheat.....	4.00	860
1894	Wheat.....	26.58	1265
1895	Wheat.....	33.00	3620
1896	Wheat.....	26.00	2980
1897	Wheat.....	14.67	1820
1898	Wheat.....	6.90	2720
1899	Wheat.....	18.20	1790
1900	Wheat.....	10.00	1740
1901	Wheat.....	27.20	3320
1902	Wheat.....	11.70	5200
1903	Wheat.....	Omitted.	
1904	Wheat.....	Omitted.	
1905	Wheat.....	Omitted.	
1906	Wheat.....	8.66	1122
1907	Wheat.....	24.80	3214
1908	Wheat.....	16.10	2087
1909	Wheat.....	21.90	2858
1910	Wheat.....	Omitted.	
1911	Wheat.....	20.25	1892
1912	Wheat.....	9.96	1386
1913	Wheat.....	20.91	3484
Average Wheat.....		19.0	2593

*6 tons manure per acre annually, 1889-1903; 7.8 tons, 1904-1913.

PLOT NO. 37

4-YEAR ROTATION: CORN, OATS, WHEAT, CLOVER

*Manured Annually.

Year	Crop	Yield	
		Grain	Forage*
1889	Clover	.....	3400
1890	Clover	.....	5550
1891	Corn	45.64	2450
1892	Oats	00.00	0000
1893	Clover	.....	4620
1894	Wheat	31.00	3280
1895	Corn	80.00	4070
1896	Timothy	.....	4250
1897	Clover	.....	5300
1898	Wheat	12.25	2920
1899	Corn	38.10	1860
1900	Oats	43.80	2600
1901	Clover	.....	1580
1902	Corn	80.70	2850
1903	Corn	69.08	3029
1904	Oats	19.91	1593
1905	Omitted.		
1906	Wheat	11.48	1488
1907	Corn	63.88	2587
1908	Oats	30.06	2405
1909	Cowpeas	.....	2952
1910	Wheat	Omitted.	
1911	Corn	31.80	4784
1912	Oats	53.82	2886
1913	Wheat	24.91	4037
Average Corn		58.4	3090
Average Oats		29.5	1897
Average Wheat		19.9	2931
Average Clover		.....	4090

* 6 tons manure per acre annually, 1889-1903; 7.8 tons, 1904-1913.

PLOT NO. 38

4-YEAR ROTATION: CORN, OATS, WHEAT, CLOVER

*Manured Annually.

Year	Crop	Yield	
		Grain	Forage
1889	Wheat	26.92	2370
1890	Corn	50.93	2800
1891	Oats	29.69	1150
1892	Clover	.....	4200
1893	Wheat	15.17	2510
1894	Corn	34.00	3580
1895	Oats	40.63	2340
1896	Clover	.....	6000
1897	Wheat	37.33	4460
1898	Corn	31.70	1600
1899	Oats	32.20	2250
1900	Clover	.....	2960
1901	Wheat	37.20	4410
1902	Corn	78.50	2700
1903	Omitted.		
1904	Clover	Omitted.	
1905	Wheat	31.81	4123
1906	Corn	Omitted.	
1907	Oats	37.78	3022
1908	Clover	.....	7254
1909	Wheat	15.70	2035
1910	Cowpeas	.....	7242
1911	Corn	33.80	6559
1912	Oats	14.42	1495
1913	Wheat	27.79	4807
Average Corn		45.8	3448
Average Oats		30.9	2051
Average Wheat		27.4	3531
Average Clover		.....	5103

* 6 tons manure per acre annually 1889-1903; 7.8 tons, 1904-1913.

PLOT NO. 39

4-YEAR ROTATION: CORN, OATS, WHEAT, CLOVER

No Manure or Fertilizer.

Year	Crop	Yield	
		Grain	Forage
1889	Wheat.....	25.83	2460
1890	Corn.....	35.29	2390
1891	Oats.....	21.57	1090
1892	Clover.....	.....	3400
1893	Wheat.....	14.00	2960
1894	Corn.....	34.29	3120
1895	Oats.....	31.56	1250
1896	Clover.....	.....	2760
1897	Wheat.....	28.67	3380
1898	Corn.....	28.20	1600
1899	Oats.....	26.30	1580
1900	Clover.....	.....	2300
1901	Wheat.....	34.00	4480
1902	Corn.....	54.00	2900
1903	Omitted.		
1904	Omitted.		
1905	Wheat.....	20.80	2696
1906	Corn.....	Omitted.	
1907	Oats.....	26.81	2145
1908	Clover.....	.....	2163
1909	Wheat.....	21.70	2812
1910	Cowpeas.....	.....	6162
1911	Corn.....	29.90	2899
1912	Oats.....	30.27	2080
1913	Wheat.....	13.76	4011
1914	Cowpeas.....	.....	5239
1915	Corn.....	49.60	4732
1916	Oats.....	30.60	1456
1917	Wheat.....	30.00	3710
1918	Clover.....	.....	2450
Average Corn.....		38.5	2940
Average Oats.....		27.9	1600
Average Wheat.....		23.6	3314
Average Clover.....		.....	2615